LEVEL I
PORTLAND CEMENT CONCRETE
Instruction Manual 2019 – 2020

TECHNICAL TRAINING
AND CERTIFICATION PROGRAM
Iowa Department of Transportation

Technical Training and Certification Program

Course Evaluation Sheet

As part of our continuing effort to improve the program, we ask that you please carefully fill out this evaluation sheet. Your responses are very important to us. We read each comment and consider your suggestions and feedback for future classes. Please use the back of the page if additional space is needed.

Course Name
(Example: PCC I, AGG Tech): ____________  Course Instructor: ________________

Location of course: (District or city): ________________

What type of agency do you work for:
  a) DOT
  b) County or City
  c) Consultant
  d) Contractor
  e) Other

Were the instructor(s) effective in helping you learn? How could they be more helpful?

Were the instructional manuals helpful and user friendly? How could they be improved?

Is there a topic you would have liked to spend more time on? Less time on?

Do you feel prepared to work as a certified tech in this area?

What are one or two things you liked best about this class?

What are one or two things you would like to see done differently in this class?

Thank you!!!
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</table>
WEBSITES USED IN TTCP CLASSES

There are 3 websites you will use as a TTCP Student. You will set yourself up as a user of each of these 3 websites. It’s important that you remember your user name and password for each site (hint: since you are setting each of them up yourself, you could use the same password for each site.)

IOWADOTU

https://learning.iowadot.gov/

This is where you register for classes and take web-based training. You can also print your training records transcripts here. Step-by-step instructions are available at https://iowadot.gov/training/technical-training-and-certification-program

DMACC CONTINUED EDUCATION REGISTRATION

This is where you will confirm your attendance at a TTCP class. Your instructor will guide you through the steps to complete the DMACC Registration. DMACC is in partnership with the Iowa DOT to administer TTCP training and must keep their own attendance records.

COMPUTER TESTING

All TTCP Exams will be done on the computer. Your instructor will guide you to the Test.Com website and assist with any registration requirements. Questions are multiple choice, and you will be able to see your score immediately as well as the questions that you missed.
## CONCRETE TESTS SUMMARY

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<tr>
<th>Test</th>
<th>IM</th>
<th>Importance</th>
<th>Requirement</th>
<th>Specifications</th>
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<tbody>
<tr>
<td>Sampling Concrete</td>
<td>327</td>
<td>To properly secure concrete samples to ensure accurate readings of air, slump, and strength.</td>
<td>When possible, sample from last point of placement. Air contents and slump vary depending on type and point of placement.</td>
<td>Varies with type of work, i.e., paving vs ready mix.</td>
</tr>
<tr>
<td>Temperature</td>
<td>385</td>
<td>To determine temperature of concrete being placed. Concrete in cold weather must attain a minimum strength to be able to withstand one freeze thaw cycle without cracking. Concrete in hot weather must be cured properly to prevent plastic shrinkage cracking.</td>
<td>During hot weather conditions, temperature of concrete may attribute to high w/c ratio, workability problems, and difficulty entraining air. Possible solutions include using ice in water, paving at night, place curing as soon as possible, etc. During cold weather, temperature may attribute to slow strength gain and indicate a need for protection. Generally, concrete hydrates best at 55 F. Temperatures below 40 F and above 90 F require attention to curing and protection.</td>
<td>2301.19 Pavement 2403.11 Structures</td>
</tr>
<tr>
<td>Slump</td>
<td>317</td>
<td>To determine the batch-to-batch consistency of a particular mix. It is not a measure of workability. May give an indication of the w/c ratio of a particular mix. Increasing slump by adding water may cause mix to segregate during placement.</td>
<td>In general, 3 to 4” slump is a maximum for normal concrete mixes. Testing not required in slipform paving because too much slump will cause the pavement edge to slump. HRWR’s may be used to increase slump (8” or more) and prevent segregation. Rule of Thumb: Adding 1 gallon of water per cubic yard increases slump 1”</td>
<td>Slipform paving – none Varies with type of work IM 204</td>
</tr>
<tr>
<td>Test</td>
<td>Page</td>
<td>Description</td>
<td>Methodology/Considerations</td>
<td></td>
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<tr>
<td>Air</td>
<td>318</td>
<td>To determine if adequate air is entrained in concrete to provide freeze-thaw resistance for long-term durability. Concrete is porous and water travels in and out of pores. Since water expands 9% when frozen, air voids provide pressure relief, otherwise the frozen water will crack the concrete.</td>
<td>In general, 6% air content for in-place concrete is required to provide protection. Specifications require higher amounts to account for loss during placement, especially with vibration. Generally, high air contents do not affect durability as air content being too low does. Main affect of higher air content is reduced strength. Rule of thumb: A 1% increase in air content decreases compressive strength approximately 5%. Varies with type of work IM 204</td>
<td></td>
</tr>
<tr>
<td>Unit Weight</td>
<td>340</td>
<td>To determine unit weight of concrete. Unit weight gives an indication of problems in batch weights and yield. Since air weighs nothing, but occupies a volume, air content may be determined from unit weight. It may also be used to give an indication of an air meter problem and used to help with correlation problems.</td>
<td>Ensure concrete is properly consolidated, struck off, and sides are cleaned. Improperly striking off surface and excess material on container will affect results. Rule of thumb: A 1% change in air content approximately equals change in unit weight of 0.5 lbs/ft³.</td>
<td></td>
</tr>
<tr>
<td>Making and Curing Beams</td>
<td>328</td>
<td>To cast and cure flexural strength beams and ensure accurate strength test. Beams used for payment or QMC should be consolidated in accordance with AASHTO T23, by rodding or vibration.</td>
<td>Ensure proper consolidation, entrapped air and voids in concrete will reduce beam strength. Improper curing will increases moisture loss in beam causing lower strengths. Since specimens are small, improper protection from cold or hot weather affects early and later strengths. Beams delivered any distance should be protected from impact loading and wrapped in wet burlap and plastic to prevent moisture loss. IM 204</td>
<td></td>
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<tr>
<td>Testing Beams Center Point</td>
<td>316</td>
<td>To determine if a pavement may be loaded or structural forms may be removed and loaded in flexure.</td>
<td>Ensure proper loading rate for accurate reading on load. Generally, 500 psi center point loading is required to open pavement to traffic. 575 psi is required for flexural loading of structural concrete. A 28 day strength of 640 psi third point loading is required for QMC paving.</td>
<td>2301.31 Pavement 2403.18 &amp; 19 Structures</td>
</tr>
<tr>
<td>Third Point</td>
<td>ASTM C 78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making and Curing Cylinders</td>
<td>315</td>
<td>To cast and cure cylinders and ensure accurate compressive strength test.</td>
<td>Ensure proper consolidation, entrapped air and voids in concrete will reduce cylinder strength. Improper curing will increase moisture loss in beam causing lower strengths. Since specimens are small, improper protection from cold or hot weather affects early and later strengths. Cylinders delivered any distance should be protected from impact loading and wrapped in wet burlap and plastic to prevent moisture loss.</td>
<td>IM 204</td>
</tr>
<tr>
<td>Testing Cylinders</td>
<td>315</td>
<td>To determine compressive strength of structures. Determining accurate compressive strength is essential to prevent failure.</td>
<td>Majority of bridges and structures designed for a minimum of 3500 psi. HPC bridges designed for a minimum of 5000 psi. Precast and prestress concrete require minimum strengths before removing from beds and transporting.</td>
<td></td>
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</tbody>
</table>
To determine strength of in-place concrete, non-destructively, using curing temperature. Since concrete gains strength with time and temperature, the time and temperature a given mix is subjected to can be related to the strength.

Maturity method involves 3 steps
1) Strength maturity relationship developed on first day paving.
2) Temperature is monitored in pavement or structure and maturity (TTF) calculated.
3) Validate curve every 90 calendar days.

General TTF values range from 900 to 2000°C•hr. Values of TTF are generally higher when using blended cements due to the slower setting characteristics. Since w/c ratio has biggest impact on strength, curve development should be performed with concrete at highest w/c ratio anticipated. Since specimens are small, beams should be protected during curve development. Temperature of beam is important, refer to IM 383. Opening of pavement or structure responsibility of engineer.
I.M. 213 discusses the Unsatisfactory Notice that Certified Technicians are given when they are not performing their job duties satisfactorily. This can be given for a number of reasons including, improper sampling and/or testing, not performing their duties and reporting in the time frame required, reporting incorrect information, etc. The technician is given one written notice, the second notice is three-month certification suspension, and the third notice is decertification. According to I.M. 213 the Certified Technician can automatically be decertified for false statements without going through the Unsatisfactory Notice procedure. The Certified Technician also needs to be aware of the false statement clause that is applicable to all federal-aid projects and the fraudulent practice clause that applies to all non-federal aid projects. **Certified Technicians need to read and be aware of U.S.C. 1020 and Iowa Code 714.8 since these do apply to them.** They read as follows:

**FEDERAL AID PROJECTS**

**IX. FALSE STATEMENTS CONCERNING HIGHWAY PROJECTS**

In order to assure high quality and durable construction in conformity with approved plans and specifications and a high degree of reliability on statements and representations made by engineers, contractors, suppliers, and workers on Federal-aid highway projects, it is essential that all persons concerned with the project perform their functions as carefully, thoroughly, and honestly as possible. Willful falsification, distortion, or misrepresentation with respect to any facts related to the project is a violation of Federal law. To prevent any misunderstanding regarding the seriousness of these and similar acts, the following notice shall be posted on each Federal-aid highway project (23 CFR 635) in one or more places where it is readily available to all persons concerned with the project:

**NOTICE TO ALL PERSONNEL ENGAGED ON FEDERAL-AID HIGHWAY PROJECTS**

18 U.S.C. 1020 reads as follows:

> “Whoever, being an officer, agent, or employee of the United States, or of any State or Territory, or whoever, whether a person, association, firm, or corporation, knowingly makes any false statement, false representation, or false report as to the character, quality, quantity, or cost of the material used or to be used, or the quantity or quality of work performed or to be performed, or the cost thereof in connection with the submission of plans, maps, specifications, contracts, or costs of construction on any highway or related project submitted for approval to the Secretary of Transportation; or

> Whoever knowingly makes any false statement, false representation, false report or false claim with respect to the character, quality, quantity, or cost of any work performed or to be performed, or materials furnished or to be furnished, in connection with the construction of any highway or related project approved by the Secretary of Transportation; or
Whoever knowingly makes any false statement or false representation as to material fact in any statement, certificate, or report submitted pursuant to provisions of the Federal-aid Roads Act approved July 1, 1916, (39 Stat. 355), as amended and supplemented;

Shall be fined not more than $10,000 or imprisoned not more than 5 years or both”

NON-FEDERAL AID PROJECTS

Iowa Code 714.8, subsection 3, defines fraudulent practices. “A person who does any of the following acts is guilty of a fraudulent practice. Subsection 3, Knowingly executes or tenders a false certification under penalty of perjury, false affidavit, or false certificate, if the certification, affidavit, or certificate is required by law or given in support of a claim for compensation, indemnification, restitution, or other payment.” Depending on the amount of money claimed for payment, this could be a Class C or Class D felony, with potential fines and/or prison.

The above codes refer to the individual making the false statement. Standard Specification Article 1102.03, paragraph C. section 5 refers to the Contractor.

Article 1102.03, paragraph C, section 5 states, “A contractor may be disqualified from bidder qualification if or when: The contractor has falsified documents or certifications, or has knowingly provided false information to the Department or the Contracting Authority.”
ROUNDING & DECIMALS

Rounding is uniform throughout the certification training. You would look at the place to the right of the number you are rounding to and if it is 5 or above round up or 4 and below round down.

Examples:

Rounding to whole numbers-
130.5 = 131  130.4 = 130  130.46 = 130

Rounding to tenths-
130.55 = 130.6  130.54 = 130.5  130.646 = 130.6

Rounding to hundredths-
130.555 = 130.56  130.544 = 130.54  130.5545 = 130.55

Rounding to thousandths-
130.5555 = 130.556  130.5544 = 130.554  130.55546 = 130.555

There are many equations used in Level II PCC to obtain percentages, weights, ratios, etc. The answers to these equations are expressed with the decimals in different locations. The following is a listing of how many places to round each answer.

Specific Gravity – hundredths – 2.62  2.77
Moisture – tenths – 2.7  0.6
Air - tenths - 6.5  5.8
Slump - 1/4 inch - 3 1/2  2 3/4
Beam Size - hundredths - 5.95  6.00  6.05
Absolute Volumes – thousandths - .082  .334
Water Cement Ratio (W/C) – thousandths - .480  .468
Cement Yield – tenths – 99.7  100.3
Pounds (lbs) – whole - 1450  385
Gallon (gal) – whole - 28  34
Cement Tons – hundredths - 2514.05  1883.27
Cubic Yards – hundredths – 117.00 54.50
(Concrete is batched in ¼ cubic yard increments)

There will be given numbers that are used in calculations that may be rounded differently than shown above. When given a number for use in a calculation, use the number in the form required. For example: 8.33 lbs./gal; 62.4 lbs. = unit weight of water, etc.
PORTLAND CEMENT CONCRETE GLOSSARY

Absolute Volume - The absolute volume of a material is the volume of the particles, including permeable and impermeable voids, but excluding the void spaces between particles.

Absorption - The increase in the mass of aggregate due to water being absorbed into the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

Acceptance - See verification.

Acceptance program- All factors that comprise the State Highway Agency's (SHA) determination of the quality of the product as specified in the contract requirements. These factors include verification sampling, testing, and inspection and may include results of quality control sampling and testing.

Admixture- Material other than water, cement, and aggregates in Portland cement concrete (PCC).

Agitation- Provision of gentle motion in Portland cement concrete (PCC) sufficient to prevent segregation and loss of plasticity.

Ambient temperature- Temperature of the surrounding air.

Apparent specific gravity- The ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of water.

Bag (of cement) - 94lb of Portland cement. (Approximately 1 ft.$^3$ of bulk cement.)

Beam Machine- A machine used to test flexural strength specimens.

Beam Mold- A container, typically 6 x 6 x 20 inches (150 x 150 x 500 mm), used to cast concrete specimens for flexural strength testing.

Cementitious Materials- cement and pozzolans used in concrete such as; Portland Cement, fly ash, silica fume, & blast-furnace slag.

Compressive Strength- The maximum resistance of concrete, or mortar, to axial loading in a compression testing machine, expressed as a force per unit area, such as pounds per square inch (psi) or megapascals (MPa).

Concrete Core Testing Apparatus (9-point testing machine) - A machine used to measure the length of cut concrete cores.

Concrete Cylinder- A cylindrical specimen of concrete, typically cast in a 4 x 8 inch (100 x 200 mm) or 6 x 12 inch (150 x 300 mm) mold, used for compressive strength testing.

Density- The ratio of mass to volume of a substance. Usually expressed in kg/m$^3$. 
Durability- The property of concrete that describes its ability to resist disintegration by weathering and traffic. Included under weathering are changes in the pavement and aggregate due to the action of water, including freezing and thawing.

Fineness modulus- A factor equal to the sum of the cumulative percentages of aggregate retained on certain sieves divided by 100; the sieves are 150, 75, 37.5, 19.0, 9.5, 4.75, 2.36, 1.18, 0.60, 0.30, and 0.15 mm. Used in the design of concrete mixes. The lower the fineness modulus, the more water/cement paste that is needed to coat the aggregate.

Flexural Strength – A concrete property measured by an unreinforced beam concrete beam and the ability to resist failure in bending. Flexural strength, or Modulus of Rupture (MR), is expressed as a force per unit area, such as pounds per square inch (psi) or megapascals (MPa) either by third point or center point loading.

Flowable Mortar- A self-consolidating, low strength material used for backfilling as an alternative to granular materials.

Fly ash- The finely divided residue captured in electrostatic precipitators, resulting from the combustion of powdered coal.

Free water- Water on aggregate available for reaction with hydraulic cement.

Ground, granulated blast furnace slag (GGBFS) - The ground, glassy material formed when molten blast-furnace slag is rapidly chilled in water. GGBFS, or slag, is a hydraulic cement.

Hydraulic cement -Cement that sets and hardens by chemical reaction with water.

Independent assurance- Unbiased and independent evaluation of all the sampling and testing procedures, equipment, and technicians involved with Quality Control (QC) and Verification/Acceptance.

Lot- A quantity of material to be controlled. It may represent a specified mass, a specified number of truckloads, or a specified time period during production.

Maturity Method- A method of estimating concrete strength based on the principle that concrete strength is directly related to age and temperature history.

Moisture content- The ratio, expressed as a percentage, of the mass of water in a material to the dry mass of the material.

Paste- Mix of water and hydraulic cement that binds aggregate in Portland cement concrete (PCC).

Permeability- The property of a material allowing it to transmit water.

Portland cement concrete (PCC) - A controlled mix of aggregate, Portland cement, and water, and possibly other admixtures.

PCC batch plant - A manufacturing facility for producing Portland cement concrete.

Quality assurance - Planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality. The overall system for providing quality in a constructed project, including Quality Control (QC), Verification/Acceptance, and Independent Assurance (IA).

Quality control (QC) - Operational, process control techniques or activities that are performed or conducted to fulfill contract requirements for material or equipment quality.

Random sampling - Procedure for obtaining non-biased, representative samples.

Saturated surface dry (SSD) - Condition of an aggregate particle when the permeable voids are filled with water, but no water is present on exposed surfaces.

Slump - Measurement of the relative consistency of concrete.

Specific gravity - The ratio of the mass, in air, of a volume of a material to the mass of an equal volume of water.

Unit weight - The ratio of weight to volume of a substance. The term "density" is more commonly used.

Verification - Process of sampling and testing performed to validate Quality Control (QC) sampling and testing and, thus, the quality of the product. Sometimes called Acceptance.

Yield - Volume of concrete produced per cubic yard.
TECHNICAL TRAINING & CERTIFICATION PROGRAM

GENERAL
The purpose of the Technical Training & Certification Program is to ensure Quality Control (QC)/Quality Assurance (QA) and Acceptance of Aggregates, Hot Mix Asphalt (HMA), Portland Cement Concrete (PCC), Soils, Erosion Control, Precast and Prestressed Concrete, and Pavement Profiles and to ensure proper documentation of quality control/quality assurance and acceptance procedures and test results by industry and Contracting Authority personnel.

This Instructional Memorandum (IM) explains the requirements to become certified and to remain certified to perform inspection and testing in the State of Iowa. This IM also describes the duties, responsibilities and the authority of persons assigned the position of Certified Technician in any of the above areas for construction or maintenance projects. Appendix C of this IM lists what tests and procedures the technician is qualified to perform for each level of certification they obtain.

Through a cooperative program of training, study, and examination, personnel of the construction industry, State DOT, and other Contracting Authorities will be able to provide quality management and certified inspection. Quality control/quality assurance and acceptance sampling, testing and inspection will be performed by certified personnel and documented in accordance with the IMs.

A technician who is qualified and holds a valid certification(s) shall perform quality control/quality assurance and acceptance at a production site, proportioning plant, or project site. Responsibilities cannot be delegated to non-certified technicians. The duties of a Certified Technician may be assigned to one or more additional Certified Technicians.

The Technical Training & Certification Program will be carried out in accordance with general policy guidelines established or approved by the Highway Division Director. A Board of Certification composed of the following members will advise the Director:

Director – Office of Construction and Materials
Representative of District Materials Engineers**
Representative of District Construction Engineers**
Representative of Associated General Contractors (AGC of Iowa)
Representative of Iowa Concrete Paving Association (ICPA)
Representative of Asphalt Paving Association of Iowa (APAI)
Representative of Iowa Ready Mixed Concrete Association (IRMCA)
Representative of Iowa Limestone Producers Association (ILPA)
Representative of County Engineers
Representative of American Council of Engineering Companies (ACEC-Iowa)
Coordinator of Technical Training & Certification Program**

** Appointed by Program Director

The Director of the Office of Construction and Materials will be the Program Director. Coordinators will be appointed by the Program Director to assist in administration of the program and to handle such planning, administration, and coordinating functions as may be needed.
TRAINING
The Iowa DOT or an agency approved by the Program Director will provide the training necessary to become certified. Producers/Contractors are encouraged to conduct their own pretraining program. A complete listing of training opportunities is available at the Technical Training & Certification Program website, https://iowadot.gov/training/technical-training-and-certification-program.

CERTIFICATION REQUIREMENTS
1. A candidate must attend Iowa DOT course instruction and pass the examination(s) for all levels of certification prepared and presented by the Program Director or someone designated by the Program Director. If the new candidate fails the examination, they will have one opportunity to retake the examination. The retake must be completed within six months of the original exam. If they fail the retake of the examination, they will need to attend the training again before taking the examination the third time. If an individual is recertifying they will have only one opportunity to take the examination. If they fail the examination they must take the applicable training before retaking the examination.

2. All prerequisites shall be met before the applicant may attend the next level of training for the certification desired. A listing of certification levels and prerequisites is located in Appendix A.

3. Once the candidate has met all the criteria and has received certification, it is recommended the Certified Technician work under the supervision of an experienced technician until they become efficient in the inspection and testing methods they will be performing.

An individual requesting to become certified as a Precast/Prestress Concrete Technician is required to obtain forty hours of experience assisting in quality control inspection at an approved plant before certification will be issued. The experience must be documented and shall be approved by the District Materials Engineer. This experience must be completed within two years from the date the individual attended the training.

4. Registered Professional Engineers, engineering graduates, and geology graduates from accredited institutions will be exempt from the training requirement in the areas they have had instruction. It is, however, strongly recommended that they attend the certification classes. In order to obtain certification for any technical level, these persons must pass all applicable written examinations for the level of certification they wish to obtain. If the written examination attempt does not meet the required score, the candidate must take the certification class before another attempt can be made. All certificates issued in accordance with these requirements will be subject to the same regulations concerning expiration, recertification, etc., as applies to certificates obtained via training and examinations.

5. Technicians will be issued certifications by reciprocity when the following criteria are met:
   a. The applicant must be certified in another state or certification program determined equivalent by the Program Director or someone designated by the Program Director, in each level of certification they are requesting.
   b. The applicant must pass an examination for each level of certification desired, which will be administered by the Iowa Department of Transportation. Failure of the examination shall require the applicant to take the applicable schooling before they can retake the exam.
c. The applicant must follow the prerequisite requirements of the Technical Training & Certification Program.

Reciprocity requests should be made through the Technical Training and Certification office in Ames. Copies of all the applicant’s certifications will be required.

CERTIFICATION
Upon successfully completing the requirements for certification, the Program Director will issue a pocket certification card. The certification is not transferable. A certification shall be valid for five years.

CERTIFICATION IDENTIFICATION
The certification card will identify the certificate holder, their certification number, the level(s) of certification, and the expiration date of each level.

RENEWAL OF CERTIFICATION
A certification shall be valid through December 31st of the fifth year. A 90-day grace period will be allowed. If the individual has not renewed their certification within the 90-day grace period, they are automatically decertified. The individual may obtain certification by taking the examination for the level of certification they are requesting. If the individual does not take the examination within one year after their certification(s) expire, i.e., 12/31/expiration year, they must retake all applicable schooling and pass the examinations. If an applicant becomes decertified in any level of certification and that certification is a prerequisite for other levels of certification the applicant will also be decertified in those related levels of certification.

All certified technicians will be required to pass an examination in each level of certification they hold before recertification will be issued. Failure of any level shall require the applicant to retake the applicable schooling and pass the test.

The certificate holder shall be responsible for applying for certification renewal and for maintaining a current address on file.

Technicians certified in Erosion Control must take one update class in the five-year period between certification and each recertification. The update is available as a web based course. If an individual does not attend the update class required before their certification expires, they must take the entire schooling and pass the examination for the certification required.

The certified technician will not receive credit for the following:

1. More than one update per training season in each level of certification.
2. An update taken during the same training season in which the individual certifies or recertifies.

PROVISIONAL CERTIFICATION
Provisional certification will be allowed through a special request to the TTCP Director. The request can be mailed or emailed to the TTCP Director and must include the need for a provisional certification, such as, company technician quit and they need to replace, an unforeseen workload, etc. Provisional certifications will only be granted to contractors. If the request is granted the following requirements will apply.

1. The provisional certification applicant must work under the direct supervision of a certified technician until such time that the applicant is competent in the required skills of
the certification and has taken the written exam. The applicant must also take the web based review offered by the TTCP in the area they are seeking provisional certification.

2. The applicant must take and pass the written exam for the provisional certification they are requesting. There will be a testing fee in the amount of the TTCP recertification fee due at the time of the exam. CIT funds may not be used for provisional certification testing. The exams will be offered at the District Materials offices or the TTCP office in Ames.

3. The technician must demonstrate proficiency to an Iowa DOT certified technician at the first available opportunity.

4. After the provisional certification applicant has successfully completed the steps in 1 and 2, they will become provisionally certified until the end of the calendar year in which they obtained certification.

5. If the provisional certified technician wishes to keep their certification they must attend the full class at the full class cost for the certification during the training season immediately following their provisional certification.

6. A provisional certification is not intended to be an annual request. The provisional certification will only be allowed for one construction season. Repeated requests for provisional certifications for the technician will be denied.

7. Any prerequisites for the certification must be met prior to number 2 above.

8. HMA Basic Tester is a new certification that may only be used as a provisional certification. This certification follows all the requirements previously listed and the technician will be required to take Level I HMA at the first available opportunity after the provisional expires.

9. Provisional Certification will be offered for:
   a. Aggregate Sampler
   b. Aggregate Technician
   c. Level I PCC
   d. HMA Sampler
   e. HMA Basic Tester

**UNSATISFACTORY PERFORMANCE NOTICE**
A certified technician failing to perform the required specified duties or inadequately performing these duties, will receive an Unsatisfactory Notice (Office of Materials IM 213, Appendix B). The notice will be from the District Materials Engineer in the District where the failure occurred. This notice and all supporting documentation will be placed in the technician’s permanent file with the District Materials Office in which the technician resides. The notice will also be placed on the statewide computer file. The notice will remain in their file for five years. The notice may be removed prior to the five years upon the recommendation of the District Materials Engineer.

**SUSPENSION**
A technician receiving two Unsatisfactory Work Performance Notices for work performed under a specific certification will be given a three-month suspension of the applicable certification. Suspended technicians shall not perform any duties governed by the suspended certification, including any duties which require the suspended certification as a prerequisite.

Technicians are eligible to be reinstated after the three-month suspension and successful completion of the applicable recertification test(s).

Technicians are subject to decertification when they receive a third Unsatisfactory Performance Notice.
The suspension will be effective on the date the Program Director issues the suspension.

**DECERTIFICATION**
Certified Technicians will be decertified for any of the following reasons:

Certifications will be revoked for the following reasons:
1. Failure of the certificate holder to renew the certificate prior to regular expiration as described above.
2. Use of false or fraudulent information to secure or renew a certificate.
3. Use of false or fraudulent documentation by the certificate holder.
4. Use of misleading, deceptive, untrue or fraudulent representations by the certificate holder.
5. Cheating on certification exams or performance evaluations. This includes removing, or attempts to remove, exam questions, answers, or other exam materials from the testing location.
6. Receipt of 3 Unsatisfactory Performance notifications, as stated above under suspension.

The Program Director, or designee, will notify an individual in writing of the intent to suspend or revoke the individual’s certification(s). Notice will also be sent to the technician’s last known employer. For DOT employees, notice will also be sent to their immediate supervisor.

An individual’s certifications will be suspended during the appeal process, and the individual can’t perform any duties governed by the certification during this time, until the first day following the end of the appeal process described below.

Technicians that are decertified shall not perform any duties requiring certification.

**APPEALS & REINSTATEMENT REQUESTS**
An individual has 10 business days to respond to the revocation notice. If the individual fails to respond with an appeal within 10 days of receipt of the original revocation notice, the suspension or revocation becomes effective on the 10th day.

Appeal step 1: First step appeals will be heard by the program director and a representative panel. The individual will have an opportunity to present information to support their continued certification to the panel. The Program Director and representative panel will then render a written decision, taking into account the technician’s actions or omissions, the existence of past infractions, and any mitigating factors. This step 1 appeal will become final if further action is not taken as described in appeal step 2 and the suspension or revocation will become effective on the day the decision is issued by the panel.

Appeal step 2: If the individual is not satisfied with the decision of the Program Director and representative panel, the individual shall, within 10 days of receipt of the written decision, submit a request for further review to the Program Director. This appeals request will be considered by the entire Certification Board. The decision of the Certification Board will be the final decision on behalf of Technical Training & Certification Program.
Any violation will remain on the violator’s record for five years, at which time the violation will be removed from their record.

A technician may request reinstatement after one year of being decertified unless the Program Director authorized a shorter period of time, which shall not be less than three months. If a reinstatement is authorized, the individual must attend and successfully complete the applicable certification courses.

FUNCTIONS & RESPONSIBILITIES
A certificate holder at each production site, project site, proportioning plant, or laboratory will perform duties. The certified technician shall perform quality control testing in accordance with specified frequencies and submit designated reports and records.

The specification requirement for materials testing by a certified technician does not change the supplier’s responsibilities to furnish materials compliant with the specification requirements.

The District Materials Engineer and/or Project Engineer will be responsible for monitoring the sampling, testing, production inspection activities and quality control performed by the contractor. A monitor shall have satisfactorily completed the training and be certified for the level of technician they are monitoring.

The District Materials Engineer and/or Project Engineer will have authority and responsibility to question and, where necessary, require changes in operations and quality control to ensure specification requirements are met.

QUALITY CONTROL, TESTING, & DOCUMENTATION
The QC Technician shall be present whenever construction work related to production activity, such as stockpiling or other preparatory work, requires record development and/or documentation is in progress. The QC Technician’s presence is normally required on a continuing basis beginning one or more days before plant operation begins and ending after plant shut down at the completion of the project. The work shall be performed in a timely manner and at the established frequencies.

The QC Technician’s presence is not normally required during temporary plant shut downs caused by conditions, such as material shortages, equipment failures, or inclement weather.

All quality control activities and records shall be available and open for observation and review by representatives of the contracting authority.

Reports, records, and diaries developed during progress of construction activities will be filed as directed by the Contracting Authority and will become the property of the Contracting Authority.

Quality control activities, testing, and records will be monitored regularly by Contracting Authority representatives. The Project Engineer or District Materials Engineer will assign personnel for this function.

Monitor activities will be reported and filed at prescribed intervals with the Project Engineer, District Materials Engineer, producer, contractor, and the contractor’s designated producer.

At no time will the monitor inspector issue directions to the contractor, or to the QC Technician. However, the monitor inspector will have the authority and responsibility to question, and where
necessary, reject any operation or completed product, which is not in compliance with contract requirements.

**ACCEPTANCE**
Completed work will be accepted on the basis of specification compliance documented by acceptance test records, and monitor inspection records. Specification noncompliance will require corrective action by the producer, contractor, or by the contractor’s designated producer, and review of events and results associated with noncompliance by the Project Engineer.
<table>
<thead>
<tr>
<th>CERTIFICATION LEVEL</th>
<th>TITLE</th>
<th>PRE-REQUISITES</th>
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<tbody>
<tr>
<td>AGGREGATE</td>
<td></td>
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<tr>
<td>Aggregate Sampler</td>
<td>Certified Sampling Technician</td>
<td>None</td>
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<tr>
<td>Aggregate Technician</td>
<td>Certified Aggregate Technician</td>
<td>None</td>
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<tr>
<td>CONTRACT ADMINISTRATION</td>
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<tr>
<td>EROSION CONTROL</td>
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<tr>
<td>Erosion Control</td>
<td>Erosion Control Technician</td>
<td>None</td>
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<tr>
<td>HOT MIX ASPHALT</td>
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<tr>
<td>HMA Sampler</td>
<td>HMA Sampler</td>
<td>None</td>
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<tr>
<td>Level I HMA</td>
<td>HMA Technician</td>
<td>Aggregate Technician</td>
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<tr>
<td>Level II HMA</td>
<td>HMA Mix Design Technician</td>
<td>Level I HMA</td>
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<tr>
<td>PORTLAND CEMENT CONCRETE</td>
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<tr>
<td>Level I PCC**</td>
<td>PCC Testing Technician</td>
<td>None</td>
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<tr>
<td>Level II PCC</td>
<td>PCC Plant Technician</td>
<td>Agg. Technician &amp; Level I PCC</td>
</tr>
<tr>
<td>Level III PCC</td>
<td>PCC Mix Design Technician</td>
<td>Level II PCC</td>
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<tr>
<td>**American Concrete Institute (ACI) Grade I certification will be acceptable as a portion of the Level I PCC training.</td>
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<tr>
<td>Prestress</td>
<td>Prestress Technician</td>
<td>Level I PCC or ACI Grade I</td>
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<td></td>
<td></td>
<td>If the technician will be performing gradations, they will need to be Aggregate Technician certified.</td>
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<tr>
<td>RIDE QUALITY</td>
<td>Ride Quality Technician</td>
<td>None</td>
</tr>
<tr>
<td>SOILS</td>
<td>Soils Technician</td>
<td>None</td>
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</tbody>
</table>
UNSATISFACTORY PERFORMANCE NOTICE

Issued To: __________________________ Date: ________________

This notice is to inform you that your performance as a Certified Inspector/Technician was unsatisfactory for the reason(s) listed below.

This notice will be placed in your permanent file with the District Materials Office in which you reside. It will also be placed on the statewide computer file.

The goal of the Technical Training and Certification Program (TTCP) is to work with contractors, producers, cities, and counties to continually improve the quality of Iowa’s construction projects. We hope you will work with us to achieve this goal.

Unsatisfactory Performance:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

_______________________________________ District Materials Engineer

cc: Program Director – Construction and Materials Engineer, Ames
TTCP Coordinator
Resident Construction Engineer
CERTIFIED TECHNICIANS QUALIFICATIONS

Tests and Procedures the Certified Technician is qualified to perform for each level of certification.

AGGREGATE SAMPLER
- IM 204 - Inspection of Construction Project Sampling & Testing (when material is incorporated)
- IM 209, App. C - Aggregate Specification Limits & Sampling & Testing Guide (when material is produced)
- IM 301 - Aggregate Sampling Methods
- IM 336 – Methods of Reducing Aggregate Field Samples to Test Samples

AGGREGATE TECHNICIAN
- IM 204 - Inspection of Construction Project Sampling & Testing (when material is incorporated)
- IM 209, App. C - Aggregate Specification Limits & Sampling & Testing Guide (when material is produced)
- IM 210 – Production of Certified Aggregate From Reclaimed Roadways
- IM 216 - Guidelines for Verifying Certified Testing Results
- IM 301 - Aggregate Sampling Methods
- IM 302 - Sieve Analysis of Aggregates
- IM 306 - Determining the Amount of Material Finer Than #200 (75µm) Sieve in Aggregate
- IM 307 - Determining Specific Gravity of Aggregate
- IM 308 - Determining Free Moisture & Absorption of Aggregate
- IM 336 - Methods of Reducing Aggregate Field Samples to Test Samples
- IM 344 - Determining the Amount of Shale in Fine Aggregate
- IM 345 - Determining the Amount of Shale in Coarse Aggregate
- IM 368 – Determining the Amount of Clay Lumps & Friable Particles in Coarse Aggregate
- IM 409 – Source Approvals for Aggregate

LEVEL II CONTRACT ADMINISTRATION
- N/A

LEVEL III CONTRACT ADMINISTRATION
- IM 101 – Review of Materials Used in Construction & Maintenance Projects
- IM 103 – Inspection Services Provided to Counties, Cities, and Other State Agencies
- IM 204 – Inspection of Construction Project Sampling & Testing

HMA BASIC TESTER (This is for Provisional Certification Only)
- IM 321 - Method of Test for Compacted Density of Hot Mix Asphalt (HMA) (Displacement Method)
- IM 322 - Method of Sampling Uncompacted Hot Mix Asphalt
- IM 323 - Method of Sampling Asphalitic Materials
- IM 325G - Method of Test for Determining the Density of Hot Mix Asphalt (HMA) Using the Superpave Gyratory Compactor (SGC)
- IM 350 - Maximum Specific Gravity of Hot Mix Asphalt (HMA) Mixtures
• IM 357 - Preparation of Hot Mix Asphalt (HMA) Mix Samples for Test Specimens
  All forms must be signed by an HMA I or HMA II certified technician

**HMA SAMPLER**
• IM 320 – Method of Sampling Compacted Asphalt Mixtures
• IM 321 – Method of Test for Compacted Density of Hot Mix Asphalt (HMA) (Displacement Method)
• IM 322 - Method of Sampling Uncompacted Hot Mix Asphalt
• IM 323 - Method of Sampling Asphaltic Materials

**LEVEL I HMA**
• IM 204 - Inspection of Construction Project Sampling & Testing
• IM 208 - Materials Laboratory Qualification Program
• IM 216 - Guidelines for Verifying Certified Testing Results
• IM 320 - Method of Sampling Compacted Asphalt Mixtures
• IM 321 - Method of Test for Compacted Density of Hot Mix Asphalt (HMA) (Displacement Method)
• IM 322 - Method of Sampling Uncompacted Hot Mix Asphalt
• IM 323 - Method of Sampling Asphaltic Materials
• IM 325G - Method of Test for Determining the Density of Hot Mix Asphalt (HMA) Using the Superpave Gyratory Compactor (SGC)
• IM 337 - Determining Thickness of Completed Courses of Base, Subbase, & Hot Mix Asphalt
• IM 350 - Maximum Specific Gravity of Hot Mix Asphalt (HMA) Mixtures
• IM 357 - Preparation of Hot Mix Asphalt (HMA) Mix Samples for Test Specimens
• IM 501 - Asphaltic Terminology, Equations & Example Calculations
• IM 508 - Hot Mix Asphalt (HMA) Plant Inspection
• IM 509 - Tank Measurement & Asphalt Cement Content Determination
• IM 511 - Control of Hot Mix Asphalt (HMA) Mixtures

**LEVEL II HMA**
• IM 380 - Vacuum-Saturated Specific Gravity & Absorption of Combined or Individual Aggregate Sources
• IM 510 - Method of Design of Hot Mix Asphalt (HMA) Mixes
• AASHTO T176 - Plastic Fines in Graded Aggregate & Soils by use of Sand Equivalent Test
• AASHTO T304 - Uncompacted Void Content of Fine Aggregate
• ASTM D 4791 - Flat Particles, Elongated Particles, or Flat & Elongated Particles in Coarse Aggregate
• AASHTO T283 Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage

**LEVEL I PCC**
• IM 204 - Inspection of Construction Project Sampling & Testing
• IM 208 - Materials Laboratory Qualification Program
• IM 216 - Guidelines for Verifying Certified Testing Results
• IM 315 - Method of Protecting, Curing, Making & Testing Concrete Cylinders
• IM 316 - Flexural Strength of Concrete
• IM 317 - Slump of Hydraulic Cement Concrete
• IM 318 - Air Content of Freshly-Mixed Concrete by Pressure
• IM 327 - Sampling Freshly-Mixed Concrete
• IM 328 - Making, Protecting, and Curing Concrete Flexural Specimens
• IM 340 - Weight Per Cubic Foot, Yield, & Air Content (Gravimetric) of Concrete
• IM 347 – Measuring Length of Drilled Concrete Cores
• IM 383 - Testing the Strength of PCC Using the Maturity Method
• IM 385 - Temperature of Freshly-Mixed Concrete
• IM 525 - Designing Flowable Mortar
• AASHTO T97 - Third Point Loading

**LEVEL II PCC**
• IM 527 - Paving Plant Inspection
• IM 528 - Structural Concrete Plant Inspection
• IM 529 - PC Concrete Proportions

**LEVEL III PCC**
• IM 530 - Quality Management & Acceptance of PC Concrete Pavement
• IM 531 - Test Method for Combining Aggregate Gradations
• IM 532 - Aggregate Proportioning Guide for Portland Cement Concrete Pavement

**PRESTRESS**
• IM 570 - Precast & Prestressed Concrete Bridge Units

**RIDE QUALITY**
• IM 341 - Determining Pavement & Bridge Ride Quality

**SOILS**
• IM 309 – Determining Standard Proctor Moisture Density Relationship of Soils
• IM 312 - Sampling of Soils for Construction Project
• IM 335 – Determining Moisture Content of Soils
• ASTM D-2937 – Field density by drive-cylinder method
AGGREGATE SAMPLING TECHNICIAN DUTIES

Duties of the Aggregate Technician are detailed in IM 209 and the IM 300 Series and consist of, but are not limited to the following:

A. Sampling

   1. Obtain representative samples by approved method(s).

   2. Sample at required frequencies.

   3. Identify samples with pertinent information such as:
      a. Type of material
      b. Intended use
      c. Production beds working depth
      d. Sampling method

   4. Reduce samples by approved method(s).
AGGREGATE TECHNICIAN DUTIES

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   3. Identify samples with pertinent information such as:
      a. Type of material
      b. Intended use
      c. Production beds working depth
      d. Sampling method
   4. Reduce samples by approved method(s).

B. Gradation Testing
   1. Follow appropriate testing methods.
   2. Maintain current applicable specifications.
   3. Post test results within 24 hours of sampling.

C. Other Testing as required (specific gravity, moisture, deleterious material, etc.)
   1. Follow appropriate testing methods.
   2. Maintain current applicable specifications.
   3. Complete required reports.

D. Sampling & Testing Equipment
   1. Clean and check testing sieves for defects.
   2. Assure scale accuracy.
   3. Maintain sampling and testing equipment.

E. Communication
1. Notify the District Materials office for production start-up or changes.

2. Relay test results to appropriate production or supervisory personnel.

3. Report failing test results immediately to appropriate personnel (including District Materials office) and assure remedial actions are taken.

F. General

1. Monitor stockpiling procedures to avoid contamination and excess segregation.

2. Assure proper identification of stockpiles.

3. Assure specification requirements for intended use are met before shipment.

4. Assure sampling locations are safe.

5. Assure proper bedding planes or production depths are maintained.

G. Documentation

1. Report all production test results of certified aggregates on Form #821278 and distribute as required.

2. Assure “plant production log” is maintained.
CONTRACT ADMINISTRATION TECHNICIAN DUTIES

Levels II and III perform duties described in Article 1105.06 “Authority & Duties of Inspector”. Duties of the Contract Administration Technician consist of, but are not limited to the following:

**Level I**

A. Field inspection on a single, or few, projects.
   1. Conduct measurements.
   2. Collect materials certifications.
   3. Perform inspection on small/medium projects.
   4. Daily log of contractor’s activities.
   5. Measure contract quantities for pay.

**Level II**

A. Lead inspector of medium-sized project or multiple small projects.
   1. Ensure work is completed according to contract documents.
   2. Ensure proper materials certifications.
   3. Coordinate and review inspector activities.
   4. Maintain project records.
   5. Prepare authorization for project progress reports and pay vouchers.
   6. Identify and report non-complying materials or activities.

**Level III**

A. Manages the inspection and documentation of large, complex highway construction projects and/or several small highway projects.
   1. Ensure work is done according to applicable contract documents, permits, laws, and other government regulations.
   2. Review project daily to ensure adequate inspection and compliance of work.
   3. Coordinate solution when contract documents do not completely and accurately address site conditions. Assists in negotiating change orders.
4. Make timely decisions to prevent non-complying work, avoid delays in project completion, and avoid potential claims due to loss of production by the contractor.

5. Perform end of project audit on incorporated materials.

6. Prepare project documents for final review.

7. Make determination on necessity of interest payment to the contractor and calculate that value.
EROSION CONTROL TECHNICIAN DUTIES

Duties of the Erosion Control Technician consist of, but are not limited to the following:

A. Carefully review and be familiar with the details in the contract documents.

B. Assign erosion and sediment control monitoring responsibilities to Erosion & Sediment Control (ESC) Basics trained field staff.

C. Review copies of storm water inspection reports.

D. Provide input on initial Erosion Control Implementation Plan (ECIP) submittal and ECIP updates.

E. Provide onsite reviews when requested by Contracting Authority or Contractor field staff.
HOT MIX ASPHALT (HMA) SAMPLING TECHNICIAN INSPECTION DUTIES

Duties of the Hot Mix Asphalt Sampling Technician consist of, but are not limited to the following:

A. Plant Sampling. (Article 2303.04, IM 204 & 511)
   1. Obtain asphalt binder samples as directed by Contracting Authority personnel per IM 323 and IM 204.

B. Field Sampling (Article 2303.04, IM 204 & 511)
   1. Obtain uncompacted mix random samples as directed by Contracting Authority personnel, and identify time, station, lift and side.
   2. Obtain compacted mix core random samples as directed by Contracting Authority personnel.
HOT MIX ASPHALT (HMA) TECHNICIAN INSPECTION DUTIES

The following is a list of the duties that must be performed by the Certified Level I HMA Technicians doing quality control work for the Contractor on all projects where the Quality Management-Asphalt (QM-A) specification applies. The Quality Control Technician shall have no other duties while performing certified inspection duties.

These duties consist of, but are not limited to, the following:

B. Aggregate Stockpiles.

1. Assure proper stockpiling of aggregate deliveries. (stockpile build & additions) (IM 508)
   a. Prevent intermingling of aggregates.
   b. Check for and prevent contamination.
   c. Prevent segregation.
   d. Check for oversize material.

2. Document certified aggregate deliveries. (each delivery) (IM 508). When the aggregate supplier can provide a summary document of all deliveries, do not enter into Plant Book.
   a. Obtain truck tickets.
   b. Check for proper certification.
   c. Check for proper approved source.
   d. Enter deliveries in Plant Book Program when other documentation cannot be provided, Aggregate Certification page.

3. Observe loader operation. (daily) (IM 508)
   a. Check for proper stockpile to bin match-up.
   b. Check that loader does not get stockpile base material in load.
   c. Check that loader does not intermingle aggregate by overloading bins.

C. Asphalt Binder Delivery. (each delivery) (IM 508 & 509)

1. Check that material is pumped into correct tank.

2. Document Deliveries.
   a. Obtain truck tickets.
   b. Check for proper approved source.
   c. Check for proper certification.
   d. Check for proper grade.
   e. Check for addition of liquid anti-strip if required.
   f. Check if weight per gallon or specific gravity has changed.
   g. Enter deliveries into Plant Report Program.
C. Plant Operations. (daily)

1. Prepare Plant Report Program for daily entries. (IM 511)
   a. Enter Date.
   b. Enter Report Number.
   c. Enter expected tonnage for the day.
   d. Enter any proportion or target changes that apply.

2. Aggregate Delivery System. (IM 508)
   a. Check for proper cold feed gate settings.
   b. Check for proper cold feed belt speed settings.
   c. Check for proper moisture setting (drum plants).
   d. Monitor RAP proportions.

3. Mixing System. (Article 2303.03, IM 508)
   a. Check for proper asphalt binder delivery setting.
   b. Check for proper interlock operation.
   c. Monitor coating of aggregates.
   d. Monitor mixing time (batch plants).

4. Loading System. (Article 2303.03 & 2001.01, IM 508)
   a. Check hopper/silo gates for proper open/close
   b. Check trucks for proper loading and possible segregation.
   c. Check trucks for diesel fuel contamination in box and remove contaminated
      trucks from service (5 hrs with box raised).

5. Asphalt Binder Quantity Determination.
   a. Obtain totalizer printout readings and periodically check against tank stick
      readings.
   b. If using batch count for quantity, obtain printouts of each batch and add up
      the asphalt binder used for total quantity.

D. Plant Operations. (2 hour intervals) (IM 508)

1. Temperatures.
   a. Monitor and record mix temperature at discharge into truck box.
   b. Monitor and record asphalt binder temperature.
   c. Monitor and record air temperature.

2. Observe plant operation for any irregularities.

E. Weighing Equipment.
1. Proportioning scales (batch plants). (min. 1/day) (Articles 2001.07 & 2001.20) (IM 508)
   a. Perform sensitivity checks of scales.
   b. Check for interference at scale pivot points.

2. Pay Quantity Scales. (min. 1/day) (Articles 2001.07 & 2001.20, IM 508)
   a. Regularly perform check weighing comparisons with a certified scale as necessary. (min. 1st day and one additional if >5000 tons, and as directed by Engineer)
   b. Perform sensitivity checks of scales.
   c. Check for interference at scale pivot points.
   d. Perform verification weighing (truck platform scales).

3. Weigh Belts. (daily)
   a. Check weigh belt for excess clinging fines that effects speed reading.
   b. Check weigh belt for interference at bridge pivot points.
   c. Check for proper span setting.

4. Enter scale checks in Plant Report Program. (daily)

F. Plant Sampling. (daily) (Article 2303.04, IM 204 & 511)

2. Obtain cold-feed gradation samples as directed by Contracting Authority personnel per IM 301 and IM 204.

3. Obtain asphalt binder samples as directed by Contracting Authority personnel per IM 323 and IM 204.

4. Obtain cold-feed moisture samples at a minimum of every ½ day (drum mix plants).

G. Field Sampling (if not performed by others). (daily) (Article 2303.04, IM 204 & 511)

1. Obtain uncompacted mix random samples as directed by Contracting Authority personnel, and identify time, station, lift and side.

2. Obtain compacted mix core random samples as directed by Contracting Authority personnel.

H. Testing. (daily) (Article 2303.04, IM 204 & 511)

1. Field cores.
   a. Provide properly calibrated equipment for Contracting Authority technician’s use.
   b. Obtain and record core location station and offset information.
c. Obtain copy of core thickness measurements from Contracting Authority Technician.
d. Obtain copy of core weights from Contracting Authority technician.
e. Record weights and thickness in Plant Report Program.

2. Uncompacted mix.
   a. Properly store Contracting Authority secured portion of paired sample.
b. Split Contractor half of paired sample into test portions as per IM 357.
c. Perform gyratory compaction as per IM 325G.
d. Perform bulk specific gravity test of laboratory-compacted specimen as per IM 321.
e. Perform maximum specific gravity test as per IM 350.
f. Enter test data into Plant Report Program.
g. Submit secured samples to DOT District Lab.

3. Aggregate.
   a. Split one sample each day as directed by Contracting Authority personnel and provide half for testing by Contracting Authority.
b. Perform gradation analysis as per IM 302 and enter weights into Plant Report Program.
c. Perform moisture tests and produce results upon request.

4. Testing Lab Qualification. (as needed) (IM 208 & 511)
   a. Record all HMA sample validations with DOT on form 235.
b. Document corrective actions taken when not correlating.
c. Document all test equipment calibrations.
d. Update IM's, test procedures and specs as required.

I. Documentation. (daily) (Article 2303.04, IM 204, 511 & 508)
The Plant Report, Chart, Plant Book, and other HMA worksheets are available on the following website: http://www.iowadot.gov/Construction_Materials/hma.html

   a. Check that all data is correct.
b. Check that all data is complete.
c. Compute tons of mix used to date.
d. Enter mix adjustment data on report.
e. Check for spec compliance.
f. Immediately report non-complying results.
g. Obtain and record mat temperatures and stationing.
h. Provide electronic daily Plant Report to DME.

   a. Record weather conditions.
b. Record daily high and low temperatures.
c. Record sunrise and sunset times.
d. Record any interruptions to plant production.
e. Record any other significant events.

3. Import daily data into charting program.

4. Enter tack shipment quantities in Plant Report Program.

5. Total all truck tickets delivered to project and deduct any waste to determine HMA pay quantity.

6. Complete Daily Check List

J. Miscellaneous. (daily) (IM 208 & 511)

1. Clean lab.

2. Back-up computer files.

3. Dispose of samples as directed by District Lab.

4. Clean and maintain lab equipment.

K. Independent Assurance Duties. (Every 3 months) (IM 205 & 216)

1. Pick up HMA and aggregate proficiency sample from District Lab.

2. Test aggregate proficiency sample for gradation per IM 302.


4. Report test results on proficiency samples to Central Materials Office per IM 205.

L. Project Duties. (1/project) (IM 508 & 511)

1. Be in possession of appropriate mix design.

2. Be present during plant calibration.

3. Observe scale calibrations.

4. Perform plant site and set-up inspection and fill out Plant Site Inspection List.

5. Set up Plant Report Program and enter all project information to create Project Master files at beginning of project.

6. Check that release agents used in truck boxes are on the approved list in MAPLE.
7. Copy all computer files and provide to the Contracting Authority at completion of project.

8. Copy all paperwork and control charts and provide to the Contracting Authority at completion of project.
PORTLAND CEMENT CONCRETE (PCC) TECHNICIAN DUTIES
PAVING & STRUCTURAL CONCRETE

The Quality Control Technician shall have no other duties while performing certified inspection duties. Refer to IM 528 for exceptions. The District Materials Engineer may approve all quality control activities be performed by a single certified technician for low production situations.

Many of the duties of the PCC Level II Technician are detailed in IM 527 (Paving) and IM 528 (Structural) and consist of, but are not limited to the following:

A. Stockpiles
   1. Assure proper stockpiling procedures.
   2. Prevent intermingling of aggregates.
   3. Prevent contamination.
   4. Prevent segregation.

B. Plant Facilities
   1. Assure safe sampling locations.
   2. Check for equipment compliance.
   3. Assure proper laboratory location and facilities.

C. Calibration
   1. Be present during calibration (paving).
   2. Check plant calibration (structural).
   3. Assure proper batch weights.

D. Cement (Fly Ash) & Aggregate Delivery
   1. Check for proper sources and certification.
   2. Document quantities delivered.
   3. Monitor condition of shipments.

E. Plant Sampling
   1. Check aggregate gradations by obtaining, splitting, and testing samples.
2. Check aggregate moistures and specific gravity.

F. Proportion Control
   1. Check scale weights and operation.
   2. Check admixture dispensers.
   3. Check mixing time and revolutions.
   4. Check cement yield. (Paving plant only, unless over 10,000 cu. yds.)

G. Concrete Tests
   1. Cure flexural test specimens.
   2. Test flexural specimens (Contract agency will perform test in structural plant).
   3. Conduct maturity testing.

H. Test Equipment
   1. Clean and maintain scales, screens, pycnometers and beam molds, and laboratory facility.

I. Documentation
   1. Prepare daily plant reports (paving), weekly plant reports (structures).
   2. Document all checks and test results in the field book.
   3. Maintain daily diary of work activity.
PRESTRESS TECHNICIAN DUTIES

Duties of the Prestress Technician are detailed in IM 570 and consist of, but are not limited to the following:

A. Pre-pour

1. Identify and document materials requiring outside fabrication inspection.
2. Identify potential fabrication or production problems and notify Iowa DOT inspectors.
3. Verify that all materials incorporated meet the requirements of the contract documents.
5. Check tension calculations.
6. Measure elongation and gauge pressure during tensioning.
7. Check hold down and insert locations.
8. Check stress distributions.
9. Check steel reinforcement and placement.
10. Check strand position.
11. Check condition of pallet.
   a. Level
   b. Holes
   c. Gaps
   d. Other deformities
12. Determine moisture of aggregates.
13. Check form condition and placement.
   a. Oil
   b. Line alignment level
   c. Tightness

B. Concrete Placement
2. Check on use of an approved mix design and batching operations (sequence).

3. Assure appropriate placement and proper vibration techniques.

4. Measure and record concrete temperature.

5. Assure test cylinders are properly made.

6. Assure appropriate finish.

7. Assure appropriate curing operations.

C. Post-pour

1. Check temperature and record during curing process.

2. Assure concrete strength has been met prior to releasing the line.

3. Assure proper detensioning procedure.

4. Check unit for defects and obtain approval for repairs.

5. Identify and store cylinders with the respective units.

6. Check beam ends for fabrication in accordance with the plans.

7. Assure exterior sides of facia beams are grouted.

8. Inspect after patching and desired surfacing.

9. Measure and record overall dimensions of beam.

10. Measure and record camber at release and compare to design camber.

11. Check and/or measure and record lateral sweep before shipping.

12. Assure proper cylinder cure.
RIDE QUALITY TECHNICIAN DUTIES

Duties of the Ride Quality Technician are detailed in IM 341 and consist of, but are not limited to the following:

A. Test pavement and bridge surfaces for ride quality.

B. Evaluate the test data.
   1. Identify bumps and dips.
   2. Summarize the roughness into segments and sections.
   3. Identify the segments for incentive, disincentive, or grind.
   4. Retest and evaluate bumps, dips, and must grid segments for specification compliance.

C. Documentation
   1. Document the evaluation on a test report. A copy is sent to the Project Engineer, District Materials Engineer, and Central Materials.
   2. Notify the Project Engineer if the daily average profile index exceeds the specification tolerance.
   3. Submit the profilograms to the Project Engineer for all areas tested.
SOILS TECHNICIAN DUTIES

A certified Soils Technician is required for all projects with Compaction with Moisture Control, Compaction with Moisture and Density Control, or Special Compaction of Subgrade (including for Recreation Trails). Refer to contract documents for Contractor QC testing requirements. Duties of the Soils Technician consist of, but are not limited to the following:

A. Sampling: Obtain samples at required frequencies per IM 204.

B. Proctor Testing

C. Other Testing as Required
   1. For projects with Compaction with Moisture Control: Determine moisture content per frequencies in IM 204.
   2. For projects with Compaction with Moisture and Density Control or Special Compaction of Subgrade: Determine moisture content and in-place density per frequencies in IM 204.

D. Sampling & Testing Equipment
   1. Clean and check testing sieves for defects.
   2. Assure scale accuracy.
   3. Check and maintain other testing equipment.

E. Evaluate the test data.
   1. For projects with Compaction with Moisture Control: Confirm soils are being placed within required moisture content range.
   2. For projects with Compaction with Moisture and Density Control or Special Compaction of Subgrade: Confirm soils are being placed within required moisture content range and soil is compacted to density equal to or greater than density requirement.

F. Documentation and Communication
   1. Document test data. A copy is sent to the Project Engineer.
   2. Relay test results to appropriate supervisory personnel.
   3. Notify the Project Engineer if any test results do not meet contract requirements and assure corrective actions are taken.
GUIDELINES FOR DETERMINING THE ACCEPTABILITY OF TEST RESULTS

GENERAL
Criteria for determining the acceptability of test results is an integral part of the Quality Assurance Program. The comparison between two different operator's results is used in the independent assurance program and sometimes in the validation process. The tolerances in this IM are for comparing individual test results except in the case of the profile index where averages are used. When criteria for comparing test results is not established in this IM or any other IM, use of the AASHTO or ASTM test procedure precision criteria is appropriate for determining acceptability of test results.

When the tolerances are exceeded, an immediate investigation must be made to determine possible cause so that any necessary corrections can be made. Below are some steps that may be used to identify the possible cause:

1. Check all numbers and calculations.
2. Review past proficiency and validation data.
3. Review sampling and testing procedures.
4. Check equipment operation, calibrations and tolerances.
5. Perform tests on split samples or reference samples.
6. Involve the Central Materials Laboratory.

TOLERANCES

<table>
<thead>
<tr>
<th>TEST NAME</th>
<th>TEST METHOD</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump of PC Concrete</td>
<td>IM 317</td>
<td>1/4 in.</td>
</tr>
<tr>
<td>1” or less on IA or Verification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 1” on IA or Verification</td>
<td></td>
<td>3/4 in.</td>
</tr>
<tr>
<td>Air Content of PC Concrete</td>
<td>IM 318</td>
<td>0.4%</td>
</tr>
<tr>
<td>Length of Concrete Cores</td>
<td>IM 347</td>
<td>0.10 in.)</td>
</tr>
<tr>
<td>NDT Pavement Thickness (MIT)</td>
<td></td>
<td>&lt;=0.15 in.</td>
</tr>
<tr>
<td>Free Moisture in Aggregate, by Pycnometer</td>
<td>IM 308</td>
<td>0.2%</td>
</tr>
<tr>
<td>Specific Gravity of Aggregate, by Pycnometer</td>
<td>IM 307</td>
<td>0.02</td>
</tr>
<tr>
<td>Moisture in Aggregate, by Hot Plate</td>
<td></td>
<td>0.3%</td>
</tr>
<tr>
<td>Moisture in Soil</td>
<td>IM 335, IM 334</td>
<td>1.5%</td>
</tr>
<tr>
<td>Proctor Optimum Moisture Content</td>
<td>IM 309</td>
<td>2.0%</td>
</tr>
<tr>
<td>Proctor Maximum Dry Density</td>
<td>IM 309</td>
<td>5.0 lb./ft³</td>
</tr>
<tr>
<td>Test Description</td>
<td>Method</td>
<td>Specific Gravity</td>
</tr>
<tr>
<td>------------------------------------------------------------</td>
<td>----------</td>
<td>--------------------</td>
</tr>
<tr>
<td>In-Place Wet Density, Soils &amp; Bases</td>
<td>IM 334, 326, other approved</td>
<td>2.0 lb./ft³</td>
</tr>
<tr>
<td>$G_{mn}$ Maximum Specific Gravity</td>
<td>IM 350</td>
<td>0.010</td>
</tr>
<tr>
<td>$G_{mb}$ Density of HMA Concrete, by Displacement</td>
<td>IM 321</td>
<td>0.020</td>
</tr>
<tr>
<td>$G^*/\sin \Delta$</td>
<td>T315</td>
<td>17% of mean</td>
</tr>
<tr>
<td>% Binder, Ignition Oven</td>
<td>IM 338</td>
<td>0.33%</td>
</tr>
<tr>
<td>$G_{sa}$ Apparent Specific Gravity</td>
<td>IM 380</td>
<td>0.010</td>
</tr>
<tr>
<td>$G_{sb}$ Bulk Specific Gravity</td>
<td>IM 380</td>
<td>0.028</td>
</tr>
<tr>
<td>Percent Absorption</td>
<td>IM 380</td>
<td>0.37%</td>
</tr>
<tr>
<td>Fine Aggregate Angularity</td>
<td>T304</td>
<td>2.0%</td>
</tr>
<tr>
<td>Sand Equivalency</td>
<td>T176</td>
<td>10% of mean</td>
</tr>
<tr>
<td>Pavement Profile Index (0.2&quot; blanking band)</td>
<td>IM 341</td>
<td></td>
</tr>
<tr>
<td>Verification Profile Index Test Result</td>
<td>Inches/mile</td>
<td></td>
</tr>
<tr>
<td>6.0 or less</td>
<td>1.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>6.1 to 20.0</td>
<td>2.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>20.1 to 40.0</td>
<td>3.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>More than 40.0</td>
<td>5.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>Pavement Profile Index (0.0&quot; blanking band)</td>
<td>IM 341</td>
<td></td>
</tr>
<tr>
<td>Verification Profile Index Test Result</td>
<td>Inches/mile</td>
<td></td>
</tr>
<tr>
<td>25.0 or less</td>
<td>3.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>25.1 to 40.0</td>
<td>4.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>More than 40.0</td>
<td>5.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>Bridge Profile Index (0.2&quot; blanking band)</td>
<td>IM 341</td>
<td></td>
</tr>
<tr>
<td>Verification Profile Index Test Result</td>
<td>Inches/mile</td>
<td></td>
</tr>
<tr>
<td>6.0 or less</td>
<td>2.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>6.1 to 20.0</td>
<td>3.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>20.1 to 40.0</td>
<td>4.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>More than 40.0</td>
<td>6.0 in./mi.</td>
<td></td>
</tr>
<tr>
<td>Pavement International Roughness Index (IRI)</td>
<td>IM 341</td>
<td></td>
</tr>
<tr>
<td>Verification IRI Test Result</td>
<td>Inches/mile</td>
<td></td>
</tr>
<tr>
<td>50.0 or less</td>
<td>10.0% of mean</td>
<td></td>
</tr>
<tr>
<td>50.1 to 150.0</td>
<td>8.0% of mean</td>
<td></td>
</tr>
<tr>
<td>More than 150.0</td>
<td>7.0% of mean</td>
<td></td>
</tr>
</tbody>
</table>
TOLERANCES FOR AGGREGATE GRADATIONS

Determining the precision of an aggregate sieve analysis presents a special problem because the result obtained with a sieve is affected by the quantity of material retained on the sieve and by results obtained on sieves coarser than the sieve in question. Tolerances are, therefore, given for different ranges of percentage of aggregate passing one sieve and retained on the next finer sieve used.

Comparisons of test results are made on each fraction of the sample, expressed in percent that occurs between consecutive sieves.

NOTE: Unless otherwise noted, tolerances for aggregate gradations are only valid if the two tests were made on a split sample. Experience has shown that improper sample reduction, as well as differences in test procedures can contribute to results being out of tolerance. When a comparison exceeds the tolerance limits, a review of the test procedures and equipment will be performed. Where practical, additional comparisons will be done with similar equipment and methods.

Table 1 Tolerances for All Aggregates Except HMA-Combined Aggregate

<table>
<thead>
<tr>
<th>Size Fraction Between Consecutive Sieves, %*</th>
<th>Tolerance, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Portion:</td>
<td></td>
</tr>
<tr>
<td>#4 Sieve and larger</td>
<td></td>
</tr>
<tr>
<td>0.0 to 3.0</td>
<td>2</td>
</tr>
<tr>
<td>3.1 to 10.0</td>
<td>3</td>
</tr>
<tr>
<td>10.1 to 20.0</td>
<td>5</td>
</tr>
<tr>
<td>20.1 to 30.0</td>
<td>6</td>
</tr>
<tr>
<td>30.1 to 40.0</td>
<td>7</td>
</tr>
<tr>
<td>40.1 to 50.0</td>
<td>9</td>
</tr>
<tr>
<td>Fine portion:</td>
<td></td>
</tr>
<tr>
<td>#8 Sieve and smaller</td>
<td></td>
</tr>
<tr>
<td>0.0 to 3.0</td>
<td>1</td>
</tr>
<tr>
<td>3.1 to 10.0</td>
<td>2</td>
</tr>
<tr>
<td>10.1 to 20.0</td>
<td>3</td>
</tr>
<tr>
<td>20.1 to 30.0</td>
<td>4</td>
</tr>
<tr>
<td>30.1 to 40.0</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2 Tolerances for All HMA-Combined Aggregate

<table>
<thead>
<tr>
<th>Size Fraction Between Consecutive Sieves, %*</th>
<th>Tolerances(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 to 3.0</td>
<td>2</td>
</tr>
<tr>
<td>3.1 to 10.0</td>
<td>3</td>
</tr>
<tr>
<td>10.1 to 20.0</td>
<td>5</td>
</tr>
<tr>
<td>20.1 to 30.0</td>
<td>6</td>
</tr>
<tr>
<td>30.1 to 40.0</td>
<td>7</td>
</tr>
<tr>
<td>40.1 to 50.0</td>
<td>9</td>
</tr>
</tbody>
</table>

(1) Minimum tolerance of 5% is applied to all size fractions coarser than the #4 sieve when comparing cold feed to ignition oven as shown on page 3 of Appendix A.

*The verification test analysis fraction is used to find the proper tolerance.
COMPARISON OF AGGREGATE GRADATIONS

Use of these tolerances is explained in the following examples. Computer spreadsheets to perform the analysis are available on the Iowa DOT Materials Office website. Use of the spreadsheets is preferred when possible. Appendix A contains a copy of the printouts from the spreadsheets.

Example 1 - PC Concrete Coarse Aggregate

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>DOT Coarse Aggr Percent Passing</th>
<th>Prod./CPI Coarse Aggr Percent Passing</th>
<th>DOT Coarse Aggr Percent Retained</th>
<th>Prod./CPI Coarse Aggr Percent Retained</th>
<th>Fraction Difference</th>
<th>Applicable Tolerance</th>
<th>Complies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5&quot;</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.9</td>
<td>2</td>
<td>Yes</td>
</tr>
<tr>
<td>1&quot;</td>
<td>97.1</td>
<td>99.1</td>
<td>2.9</td>
<td>0.9</td>
<td>2.0</td>
<td>2</td>
<td>Yes</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>72.2</td>
<td>65.1</td>
<td>24.9</td>
<td>34.0</td>
<td>9.1</td>
<td>6</td>
<td>No</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>38.1</td>
<td>34.9</td>
<td>34.1</td>
<td>30.2</td>
<td>3.9</td>
<td>7</td>
<td>Yes</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>12.0</td>
<td>8.8</td>
<td>26.1</td>
<td>26.1</td>
<td>0.0</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>#4</td>
<td>0.6</td>
<td>0.2</td>
<td>11.4</td>
<td>8.6</td>
<td>2.8</td>
<td>5</td>
<td>Yes</td>
</tr>
<tr>
<td>#8</td>
<td>0.5</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>Minus #200</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>1</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The size fraction between consecutive sieves is found by calculating the difference between the percent passing reported for the two sieves. For example, the fraction between the 1.5 in. and 1 in. sieves for the above verification test is 100.0 - 97.1 = 2.9%. Between the 1/2 in. and 3/8 in. sieves it is 38.1 – 12.0 = 26.1%. Since nothing passes the pan, the size fraction between the #200 sieve and the pan is equal to the percent passing the #200.

The example shows the fraction between each pair of consecutive sieve sizes for both tests and the difference between these fractions for both tests. The difference is compared with the applicable tolerance to determine a disposition. In this example, a suspect result is found in the fraction between the 1 in. and 3/4 in. sieves. Since the suspect difference is due primarily to the percent passing results on the 3/4 in. sieves, it is these results that should at least be investigated first. Only further investigation can determine which 3/4 in. sieve, if any is faulty.

NOTE: The applicable tolerance changes between #4 and #8 size fractions.
## Example 2 - PC Concrete Fine Aggregate

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>DOT Fine Aggregate Percent Passing</th>
<th>Prod./CPI Fine Aggregate Percent Passing</th>
<th>DOT Fine Aggregate Percent Retained</th>
<th>Prod./CPI Fine Aggregate Percent Retained</th>
<th>Fraction Difference</th>
<th>Applicable Tolerance</th>
<th>Complies</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
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## Example 3 - HMA Combined Aggregate

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<th>3/8&quot;</th>
<th>4&quot;</th>
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<th>16</th>
<th>30</th>
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<th>200</th>
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<table>
<thead>
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<th>D.O.T. % Retained</th>
<th>Prod./C.P.I. % Retained</th>
<th>Tol. %</th>
<th>Comply (Y/N)</th>
<th>Sieve Fraction Between Consecutive Sieves, %</th>
<th>Tolerance, %</th>
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</tbody>
</table>

D.O.T. FBR: _______
NOTE: The applicable tolerance for this combined aggregate sample is from Table 2. In this example, the suspect fractions would indicate a possible problem for two pairs of consecutive sieve sizes involving the #4 sieves. This evidence and the difference in the test values found for the #4 sieves, strongly point to an error in one of the #4 sieve results.

When RAP mixes are used, the comparison data is of the composite gradation results and not of the cold feed.

Example 4 HMA Cold-Feed to Ignition Oven Comparison

<table>
<thead>
<tr>
<th>Sieve Sizes - Percent Passing</th>
<th>Specs.</th>
<th>1 1/2&quot;</th>
<th>1&quot;</th>
<th>3/4&quot;</th>
<th>1/2&quot;</th>
<th>3/8&quot;</th>
<th>#4</th>
<th>#8</th>
<th>#16</th>
<th>#30</th>
<th>#50</th>
<th>#100</th>
<th>#200</th>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Correction Factor</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>-0.3</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.3</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

When comparing an ignition oven extracted gradation to a cold-feed gradation a correction factor must be applied to the ignition oven extracted gradation before comparing it to the cold-feed gradation. The correction factor is determined by calculating the difference between a cold-feed gradation and an ignition oven gradation on the first day of HMA production according to IM 501. The correction factor is then applied to all subsequent comparisons. In the example above, the correction factor was determined on a previous sample. The District Materials Engineer may establish new or average correction factors when needed.
PC CONCRETE GRADATION COMPARISON REPORT
(Computer Spreadsheet Available on Iowa DOT Office of Materials Web Site)

Iowa Department Of Transportation
Reported Gradation & IM 216 Comparison Report

<table>
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<td>Contr./Prod.</td>
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<table>
<thead>
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<th>Contr./Prod. % Retained</th>
<th>Diff. %</th>
<th>Comply (Y/N)</th>
<th>Size Fraction Between Consecutive Sieves, %</th>
<th>Tolerance, %</th>
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<td>1 1/2&quot;</td>
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<td>2 Y</td>
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<td>1 - 3/4</td>
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<td>2 Y</td>
<td>3.1 to 10.0</td>
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</tr>
<tr>
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<td>0.0</td>
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<td>10.1 to 20.0</td>
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<tr>
<td>1/2 - 3/8</td>
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<td>20.1 to 30.0</td>
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<td>0.0</td>
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<td>30.1 to 40.0</td>
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<td>0.0</td>
<td>1 Y</td>
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Remarks:

Distribution____ Central Materials____ Dist. Materials____ Contr./Producer____ Proj. Engineer____ Technician____
HMA GRADATION COMPARISON REPORT
(Computer Spreadsheet Available on Iowa DOT Office of Materials Web Site)

Iowa Department Of Transportation
Reported Gradation & IM 216 Comparison Report

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<th>Per Cent</th>
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<th>Diff.</th>
<th>Tolerance</th>
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Remarks:

Distribution________ Central Materials________ Dist Materials________ Contr./Producer________ Proj. Engineer________ Technician________
**Iowa Department Of Transportation**

**Cold-Feed & Ignition Oven Gradation & I.M. 216 Comparison Report**

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**Remarks:**

**Distribution______ Central Materials_______ Dist Materials_______ Contr./Producer_______ Proj. Engineer_______ Technician_______**
## QMC Gradation Comparison Report

(Computer Spreadsheet Available on Iowa DOT Office of Materials Web Site)

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Care of Equipment:  
○ GOOD  ○ FAIR  ○ POOR  Comments:

Sampling Procedure:  
○ GOOD  ○ FAIR  ○ POOR  Comments:

Splitting Procedure:  
○ GOOD  ○ FAIR  ○ POOR  Comments:

Sending to Completion:  
○ GOOD  ○ FAIR  ○ POOR  Comments:

Comparisons:  
○ GOOD  ○ FAIR  ○ POOR  Comments:

Reporting:  
○ GOOD  ○ FAIR  ○ POOR  Comments:
INSPECTION OF CONSTRUCTION PROJECT
SAMPLING & TESTING

INTRODUCTION
The Iowa Department of Transportation (DOT) has established a Quality Assurance Program (IM 205) to assure that the quality of materials and construction workmanship incorporated into all highway construction projects is in reasonable conformity with the requirements of the approved plans and Specifications, including approved changes. It consists of an Acceptance Program and an Independent Assurance Program (IAP), both of which are based on test results obtained by qualified persons and equipment.

The acceptance portion of the program covers quality control (QC) sampling and testing and verification sampling and testing. The IAP portion of the program covers the evaluation of all sampling and testing procedures, personnel, and equipment used as part of an acceptance decision (includes contractor, contracting agency, and consultant).

ACCEPTANCE PROGRAM FOR MATERIALS
To fulfill the materials acceptance requirements, several methods are used by the DOT.

Sampling & Testing (Test Report)
Certification
Approved Brands
Approved Sources
Approved Shop Drawings
Approved Catalog Cut
Inspection Report
Visual Approval by the Engineer

The Instructional Memorandum IM 204 Appendices A through W contain the material acceptance information for the type of work being done. If there is a conflict in wording between the appendix and another Instructional Memorandum or appendix Z, the appendix A through W will supersede the others.

In many cases more than one method may be required for acceptance in the 204 Appendices and tables in the back of this guide. For some new or special materials, the District Materials Engineer may need to determine the most appropriate acceptance requirements.

In order to provide the Contractor the opportunity to construct a project with minimal sampling and testing delays, inspection is performed at the source for many materials. Source inspection may consist of inspecting process control, sampling for laboratory testing or a combination of these procedures. All source-inspected or certified materials are subject to inspection at the project site prior to being incorporated into the work. Project site inspections are for identification of materials with test reports and for any unusual alterations of the characteristics of the material due to handling or other causes. Verification samples secured by project agency personnel of source-inspected, certified, or project processed materials are also required for some materials in order to secure satisfactory validation for acceptance.
When certification procedures are required, the Contractor may, on the Contractor’s own responsibility and at the Contractor’s risk, incorporate these materials into the work. Acceptance will be based on satisfactory certification and compliance of the test results of any verification samples. When verification samples are not taken, acceptance will be based on satisfactory certification.

A. SAMPLING & TESTING (TEST REPORT)
When a material is sampled and tested, the results will be documented on a construction form or a test report. There is quality control sampling and testing done by the Contractor or producer and verification sampling testing done by the Project Engineer, the District Materials Engineer, the Central Materials Laboratory, or an independent laboratory.

In many cases, in addition to sampling and testing, some other type of acceptance method will also be required. Sampling and testing may be done at the project, supplier, or source depending on which is the most appropriate.

B. CERTIFICATION OF COMPLIANCE
For many materials, a fabricator, manufacturer, or supplier is required to provide the Project Engineer with a certification document stating that the material meets the requirements of the plans and specifications. In most cases, the fabricator, manufacturer, or supplier must also be on an approved list in the Materials Approved Products Listing Enterprise (MAPLE). For some of these materials, sampling and testing is also required before final acceptance. The certification comes in a variety of forms:

- Stamped or preprinted on truck tickets as with aggregates,
- Stamped or preprinted on invoices as with Portland Cement and asphalt binder,
- Stamped or printed on the Mill Analysis as with reinforcing steel, structural steel, and other metals,
- Furnished as a separate document with each shipment as with zinc-silicate paint, engineering fabrics, epoxy coatings, and dowel baskets,
- Stamped or printed on a list of materials for each shipment as with CMP, concrete pipe, and corrugated plastic subdrain,

The inspector will verify that the certification has been entered into DocExpress.

C. APPROVED SOURCE
(May also be referred to as “Approved Producer, Approved Supplier, Approved Fabricator, or Approved Brand”) The source, producer, and the material must be evaluated and approved by the Office of Construction and Materials according to the appropriate Materials IM in order to be used on a project. Once a letter of approval is issued, the source or producer is approved for use on projects (with the exception of steel fabricators and precast concrete plants). Approved products, sources, and producers are listed in the Materials Approved Products Listing Enterprise (MAPLE). Approval for a source or producer may be rescinded at any time if it no longer meets the requirements of the IM. The plans, developmental specifications, and special provisions may also contain lists of approved sources.
The project inspector will document information about this material such as product name, source, date, producer, and lot number in the project files.

Most approved sources also require a certification.

D. APPROVED WAREHOUSE STOCK
For some items made up of miscellaneous materials, inspection and approval will be done by the District Materials Engineer at the supplier’s warehouse.

E. APPROVED SHOP DRAWING & APPROVED CATALOG CUT
This information must be submitted to, and reviewed by the Iowa DOT Design Office or Bridges and Structures Office, before the material can be incorporated in the project.

F. INSPECTION REPORT
The project inspector must have a copy of the final inspection report prior to incorporating the item into the project. The report will vary depending on the Materials IM requirements for the item fabricated. Final acceptance is by construction personnel at the project site, and is based on the proper documentation and the condition of the component.

G. VISUAL APPROVAL BY PROJECT ENGINEER
(May also be referred to as “As Per Plan, Approved By RCE, or Manufacturer Recommendations”) The project inspector must document information about this material such as product name, source, producer, lot number and date produced in the project files. The inspector will make sure the material meets the requirements of the plans, the Engineer, or the manufacturer before the material is used. Visual approval requires construction personnel to visually inspect the material to determine if it complies with the specifications. Visual approval is appropriate for non-critical items such as sod stakes, where compliance can be readily determined by visual means. If there are questions on specification compliance, samples will be taken for testing.

INDEPENDENT ASSURANCE PROGRAM
The IAP evaluates all sampling and testing procedures, personnel, and equipment used as part of an acceptance decision (Includes Contractor, Contracting Agency, and consultant). Independent assurance includes evaluation based on:

Calibration checks
Split samples
Proficiency samples
Observation of sampling and testing performance

The test method and the frequency of test are in the Appendices. Calibration checks and proficiency samples testing is covered in IM 208.

SMALL QUANTITIES
The FHWA allows and encourages alternative acceptance methods for small quantities of non-critical materials. Appendix X contains a list of those materials and maximum quantities for which alternative acceptance methods may be appropriate. The Project Engineer or District Materials Engineer may still require the normal acceptance method for a material when it is considered critical in the intended application.
IM 204 APPENDIXES
Appendix A  Roadway & Borrow Excavation & Embankments
Appendix B  Soil Aggregate Subbase
Appendix C  Modified Subbase
Appendix D  Granular Subbase
Appendix E  Portland Cement Concrete Pavement, Pavement Widening, Base Widening, Curb & Gutter & Paved Shoulders
Appendix F  Asphalt Mixtures
Appendix H  Structural Concrete, Reinforcement, Foundations & Substructures, Concrete Structures, Concrete Floors, & Concrete Box, Arch & Circular Culverts
Appendix I  Concrete Drilled Shaft Foundations
Appendix K  Cold-In-Place Recycled Asphalt Pavement
Appendix L  Granular Surfacing/Driveway Surfacing
Appendix M  Concrete Bridge Floor Repair & Overlay & Surfacing
Appendix P  Surface Treatment (Seal Coat, Microsurfacing, Slurry, Joint Repair, Crack Filling & Fog Seal)
Appendix T  Base Repair, Pavement Repair
Appendix U  Granular Shoulders
Appendix V  Subdrains
Appendix W  Water Pollution Control, Erosion Control
Appendix X  Acceptance of Small Quantities of Materials
Appendix Z  Supplemental Guide, Basis of Acceptance
# Sampling & Testing Guide - Minimum Frequency

**PORTLAND CEMENT CONCRETE PAVEMENT, PAVEMENT WIDENING, BASE WIDENING**

**Curb & Gutter, & Paved Shoulders**

October 15, 2019

Supersedes April 16, 2019

Section 2122, 2201, 2213, 2301, 2302, 2310, Quality Management Concrete (QM-C)

Appendix E (US) Units

<table>
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<th>METHOD OF ACCEPTANCE &amp; RELATED IMs</th>
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<th>INDEPENDENT ASSURANCE &amp; VERIFICATION S&amp;T</th>
<th>REMARKS</th>
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<tr>
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<td>AB</td>
<td>403</td>
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<td>Joint Sealer (4136.02)</td>
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AS-Approved Source

Certification Statement

RCE-Resident Construction Engineer/Project Engineer

IA-Independent Assurance

DME-District Materials Engineer

V-Verification

CTRL-Central Laboratory

M-Monitor

CONTR-Contractor

QMC-Quality Management Concrete

NOTE: RCE/CONTR indicates that the contractor shall assist in the sampling at the direction of and witnessed by the project engineer.

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(1) DME may waive sampling of water from an established well that has shown past compliance.
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<th>REMARKS</th>
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<td>SAMPLE SIZE</td>
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<td>Dowels</td>
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<td>AS</td>
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<td></td>
<td></td>
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<tr>
<td>Tie Bars</td>
<td>Quality</td>
<td>AS</td>
<td>451</td>
<td></td>
<td></td>
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<td>Quality</td>
<td>AS</td>
<td>451</td>
<td></td>
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<td>IM 301</td>
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<td>Contr</td>
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<td>Contr</td>
<td>IM 527</td>
<td>1000 gm</td>
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<td>Quality</td>
<td>AS</td>
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</table>

**NOTE:** IA may be accomplished by system approach or on a per project basis (IA at 1 per 100,000 sy of concrete) at the discretion of the DME.

**NOTE:** When Certified Plant Inspection is not provided, the engineer is responsible for performing quality control sampling and testing.

**NOTE:** RCE/Contr indicates that the contractor shall assist in the sampling at the direction of and witnessed by the project engineer.

**NOTE:** For Local agency projects with no Federal Funds Independent Assurance, IA, tests are not required.

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### Sampling & Testing Guide-Minimum Frequency

**PORTLAND CEMENT CONCRETE PAVEMENT, PAVEMENT WIDENING, BASE WIDENING**

**Curb & Gutter, & Paved Shoulders**

October 15, 2019

Supersedes April 16, 2019

Section 2122, 2201, 2213, 2301, 2302, 2310, Quality Management Concrete (QM-C)

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<th>REMARKS</th>
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<td>SAMPLE BY FREQ. SAMPLE SIZE TEST BY REPORT</td>
<td>S&amp;T TYPE SAMPLE BY FREQ. SAMP. SIZE TEST BY REPORT</td>
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<td>CONTR QMC 1/1500 cy IM 301 CONTR</td>
<td>800240</td>
<td>V RCE/ CONTR Sample 1/day,test 1st day+2/-week IM 301 RCE DME</td>
<td>IM 530 for intermittent production</td>
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<td></td>
<td>Grad Non-QMC 302 306 336</td>
<td>CONTR 1/day IM 301 CONTR</td>
<td></td>
<td>V RCE/ CONTR Sample 1/day, test 1st day + 1/week IM 301 RCE DME</td>
<td>IM 527 for intermittent or low production</td>
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<td>Moist 308</td>
<td>CONTR IM 527 IM 301 CONTR</td>
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<td>V DME 1/100,000 sy 15 lb CTRL</td>
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<td>Quality AS Cert</td>
<td>Each Load</td>
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<td>V DME 1/100,000 sy 15 lb CTRL</td>
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<tr>
<td>GGBFS(Ground Granulated Blast Furnace Slag)</td>
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<td>Each Load</td>
<td></td>
<td>V DME 1/100,000 sy 15 lb CTRL</td>
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<td>Air Admixture</td>
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<td>M DME 1/project 1 pint CTRL</td>
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<td>Retarding Admixture</td>
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<td>M DME 1/project 1 pint CTRL</td>
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</tbody>
</table>

**AS-Approved Source**

**Cert- Certification Statement**

**RCE-Resident Construction Engineer/Project Engineer**

**DME-District Materials Engineer**

**CTRL-Central Laboratory**

**CONTR-Contractor**

**IA-Independent Assurance**

**V-Verification**

**M-Monitor**

**QMC-Quality Management Concrete**

**NOTE:** IA may be accomplished by system approach or on a per project basis (IA at 1 per 100,000 sy of concrete) at the discretion of the DME.

**NOTE:** When Certified Plant Inspection is not provided, the engineer is responsible for performing quality control sampling and testing.

**NOTE:** Quality samples not required when mix quantity is less than 2000 sq. yds., except for curing compound.

**NOTE:** RCE/CONTR indicates that the contractor shall assist in the sampling at the direction of and witnessed by the project engineer.

**NOTE:** For Local agency projects with no Federal Funds Independent Assurance, IA, tests are not required.

**NOTE:** For Local agency projects with no Federal funding, verification samples or monitor samples sampled by the DME are not required. These samples may be sampled by the contracting authority. With prior approval, these samples may be tested by the Iowa Department of Transportation Central Laboratory.
### Sampling & Testing Guide - Minimum Frequency

**PORTLAND CEMENT CONCRETE PAVEMENT, PAVEMENT WIDENING, BASE WIDENING**

**CURB & GUTTER, & PAVED SHOULDERS**

October 15, 2019  
Supersedes April 16, 2019

Section 2122, 2201, 2213, 2301, 2302, 2310, Quality Management Concrete (QM-C)  
Appendix E (US) Units  
Matls. IM 204

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<td>AS-Approved Source</td>
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<td></td>
<td>CONTR-Contractor</td>
<td>QMC-Quality Management Concrete</td>
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*IA thickness cores sent to Central Lab for additional project information testing (Interstate and Primary only.) **None required when maturity is used.

NOTE: IA may be accomplished by system approach or on a per project basis (IA at 1 per 100,000 sq. yd of concrete or as noted in the table) at the discretion of the DME.

NOTE: Quality samples not required when mix quantity is less than 2000 sq. yd, except for curing compound.

NOTE: RCE/CONTR indicates that the contractor shall assist in the sampling at the direction of and witnessed by the project engineer.

NOTE: Form #E115 available from the Construction & Materials Bureau.

NOTE: For Local agency projects with no Federal Funds Independent Assurance, IA, tests are not required.

NOTE: For Local agency projects with no Federal funding, verification samples or monitor samples sampled by the DME are not required. These samples may be sampled by the contracting authority. With prior approval, these samples may be tested by the Iowa Department of Transportation Central Laboratory.
# Sampling & Testing Guide - Minimum Frequency

## PORTLAND CEMENT CONCRETE PAVEMENT, PAVEMENT WIDENING, BASE WIDENING

**Curb & Gutter, & Paved Shoulders**

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<td>CONTR</td>
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<tr>
<td></td>
<td>Air Non-QMC</td>
<td>318 327</td>
<td>CONTR</td>
<td>1/350 cy, 1/100 cy ready mix</td>
<td>CONTR</td>
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<td>Slump</td>
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<td>CONTR</td>
<td>1/700 cy, 1/100 cy ready mix</td>
<td>CONTR</td>
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<td>341</td>
<td>CONTR</td>
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</table>

**NOTE:** IA may be accomplished by system approach or on a per project basis (IA at 1 per 100,000 sy of concrete or as noted in the table) at the discretion of the DME.

**NOTE:** Quality samples not required when mix quantity is less than 2000 sq. yds., except for curing compound.

**NOTE:** RCE/CONTR indicates that the contractor shall assist in the sampling at the direction of and witnessed by the project engineer.

**NOTE:** Form #E115 available from the Construction & Materials Bureau.

**NOTE:** For Local agency projects with no Federal Funds Independent Assurance, IA, tests are not required.

**NOTE:** For Local agency projects with no Federal funding, verification samples or monitor samples sampled by the DME are not required. These samples may be sampled by the contracting authority. With prior approval, these samples may be tested by the Iowa Department of Transportation Central Laboratory.

**NOTE:** For Local agency projects with no Federal funding, smoothness verification testing may be tested and evaluated by the DME.

*IA thickness cores sent to Central Lab for additional project information testing (Interstate and Primary only) **None required when maturity is used.

**NOTE:** Quality samples not required when mix quantity is less than 2000 sq. yds., except for curing compound.

**NOTE:** RCE/CONTR indicates that the contractor shall assist in the sampling at the direction of and witnessed by the project engineer.

**NOTE:** Form #E115 available from the Construction & Materials Bureau.

**NOTE:** For Local agency projects with no Federal Funds Independent Assurance, IA, tests are not required.

**NOTE:** For Local agency projects with no Federal funding, verification samples or monitor samples sampled by the DME are not required. These samples may be sampled by the contracting authority. With prior approval, these samples may be tested by the Iowa Department of Transportation Central Laboratory.

**NOTE:** For Local agency projects with no Federal funding, smoothness verification testing may be tested and evaluated by the DME.
**Sampling & Testing Guide-Minimum Frequency**

**STRUCTURAL CONCRETE, REINFORCEMENT, FOUNDATIONS & SUBSTRUCTURES, CONCRETE STRUCTURES, CONCRETE FLOORS, & CONCRETE BOX, ARCH & CIRCULAR CULVERTS**

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**NOTE:** For Local agency projects with no Federal funding, verification samples or monitor samples sampled by the DME are not required. These samples may be sampled by the contracting authority. With prior approval, these samples may be tested by the Iowa Department of Transportation Central Laboratory.

(2) DME may waive sampling of water from an established well that has shown past compliance.

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AS-Approved Source  
ASD-Approved Shop Drawing  
S&T-Sampling & Testing  
AB-Approved Brand  
Cert – Certification Statement  
RCE-Resident Construction Engineer/Project Engineer  
DME-District Materials Engineer  
CTRL-Central Laboratory  
CONTR-Contractor  
IA-Independent Assurance  
V-Verification  
M-Monitor
# Sampling & Testing Guide—Minimum Frequency

**STRUCTURAL CONCRETE, REINFORCEMENT, FOUNDATIONS & SUBSTRUCTURES, CONCRETE STRUCTURES, CONCRETE FLOORS, & CONCRETE BOX, ARCH & CIRCULAR CULVERTS**

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# Sampling & Testing Guide—Minimum Frequency

**Structural Concrete, Reinforcement, Foundations & Substructures, Concrete Structures, Concrete Floors, & Concrete Box, Arch & Circular Culverts**

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# Sampling & Testing Guide-Minimum Frequency

**STRUCTURAL CONCRETE, REINFORCEMENT, FOUNDATIONS & SUBSTRUCTURES, CONCRETE STRUCTURES, CONCRETE FLOORS, & CONCRETE BOX, ARCH & CIRCULAR CULVERTS**

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<td>AS</td>
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</table>

NOTE: IA may be accomplished by system approach or on a per project basis (IA at 1 per 1000 cy of concrete) at the discretion of the DME according to IM 207.

NOTE: For Local agency projects with no Federal funding, Independent Assurance, IA, tests are not required.

NOTE: For Local agency projects with no Federal funding, verification samples or monitor samples sampled by the DME are not required. These samples may be sampled by the contracting authority. With prior approval, these samples may be tested by the Iowa Department of Transportation Central Laboratory.
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**NOTE:** These verification samples for concrete materials not required when mix quantity is less than 50 cu. yd. For placements greater than 1000 cu. yd., sample 1/placement.

**NOTE:** IA may be accomplished by system approach or on a per project basis (IA at 1 per 1000 cy of concrete) at the discretion of the DME according to IM 207.

**NOTE:** RCE/CONTR indicates that the Contractor shall assist in the sampling at the direction of and witnessed by the Project Engineer.

**NOTE:** Cylinders for strength on primary project bridge decks only and where specifically called for in the plans or specifications.

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*Available from the Construction and Materials Bureau.
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### Materials IM 204

#### Grade Inspection

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### AS-Approved Source
- Cert – Certification Statement

### ASD-Approved Shop Drawing
- RCE-Resident Construction Engineer/Project Engineer
- DME-District Materials Engineer
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### Material or Construction Item

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**NOTE:** RCE/CONTR indicates that the Contractor shall assist in the sampling at the direction of and witnessed by the Project Engineer.

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**NOTE:** For Local agency projects with no Federal funding, smoothness verification testing may be tested and evaluated by the DME.
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**October 15, 2019**

**CONCRETE BRIDGE FLOOR REPAIR & OVERLAY & SURFACING**

Section 2413

Matls. IM 204

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## Sampling and Testing Guide - Minimum Frequency

**October 15, 2019**

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### PLANT INSPECTION (cont)

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### Sampling and Testing Guide-Minimum Frequency

**October 15, 2019**  
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<td>DME</td>
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**AS-Approved Source**  
ASD-Approved Shop Drawing  
S&T-Sampling & Testing  
Cert- Certification Statement  
RCE-Resident Construction Engineer/Project Engineer  
DME-District Materials Engineer  
CTRL-Central Laboratory  
CONTR-Contractor  
IA-Independent Assurance  
V-Verification  
M-Monitor

(1) Nuclear density testing frequency for each placement shall be one test within 5 feet of the beginning and end of the placement and additional tests shall be equally spaced a maximum of 100 feet throughout the length of the placement. Each placement shall have a minimum of three nuclear density tests.

(2) For Class O on daily pours of more than 300 square yards, the minimum frequency will be 1 test per 100 square yards for the first 300 square yards, then 1 test for every 300 square yards for the remainder of the day’s pour.

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**NOTE:** For Local agency projects with no Federal funding, smoothness verification testing may be tested and evaluated by the DME.
**SAMPLING FRESH CONCRETE**

Concrete is required to be sampled at the plant or project site for use in a variety of tests. Concrete samples need to be representative of the concrete being poured on a project.

Concrete is sampled by both contractors and agencies for use in tests to determine air, slump, unit weight, and temperature and for making strength specimens.

Test results will not be accurate unless the sample used to run these tests was properly secured. Concrete should be sampled from the last point of placement unless it is being secured from a mixer truck. Improper sampling or sampling from an incorrect location could cause air content and slump to vary which could affect the strength of the concrete.

IM 327 explains the proper sampling procedure for fresh concrete.

---

**When the concrete sample is taken....time is important!**

**Within 5 minutes...**

- COMPLETE Temperature (IM 385)
- START Slump test (IM 317)
- START Air Content test (IM 318)

**Within 15 minutes...**

- START molding specimens for strength tests (IM 328)

Remember.... Complete tests as quickly as possible!
SAMPLING FRESHLY MIXED CONCRETE

SCOPE

This procedure provides instruction for obtaining samples of fresh concrete for new construction or repair. Sources covered include grade, ready mix truck, mobile mixer, pump or conveyor placement systems, and concrete slab as placed.

SIGNIFICANCE

Testing fresh concrete in the field begins with obtaining and preparing the sample to be tested. Standardized procedures for obtaining a representative sample from various types of mixing and/or agitating equipment have been established. Specific time limits regarding when tests for temperature, slump, and air content must be started and for when the molding of test specimens must begin are also established.

Technicians must refrain from obtaining the sample too quickly. Doing so would be a violation of the specifications under which the concrete is being supplied and it may result in a nonrepresentative sample of concrete. Every precaution must be taken to obtain a sample that is truly representative of the entire batch and then to protect that sample from the effects of evaporation, contamination, and physical damage.

PROCEDURE

A. Apparatus

1. Wheelbarrow or other nonabsorbent container
2. Cover for wheelbarrow or container (plastic, canvas, or burlap)
3. Shovel
4. 5-gallon bucket for water

B. Testing Procedure

For acceptance testing, obtain representative samples from the last practical point before incorporation, but before consolidation. The DME may adjust sample location and target air content, to ensure safe sampling location and adequate in place air content is achieved for freeze-thaw durability.

1. Sampling from Grade

   Sample after the concrete in the transport vehicle has been discharged onto the grade. To ensure a representative sample, obtain concrete from at least five different locations in the pile and combine into one test sample. Avoid contamination with subgrade material or prolonged contact with absorptive subgrade.
2. Sampling from Ready Mix Truck

Sample the concrete after a minimum of 1/2 yd.\(^3\) of concrete has been discharged. Do not obtain samples until after all of the water has been added to the mixer. Do not obtain samples from the very first or last portions of the batch discharge. Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

3. Sampling from Mobile Mixer

Discharge the concrete into a container or power buggy sufficiently large enough to accommodate the entire batch. Secure a representative sample after the batch has been deposited by obtaining one shovel full, more or less, from each of at least three different positions in the container or power buggy.

4. Sampling from Pump or Conveyor Placement Systems

Sample after a minimum of 1/2 yd.\(^3\) of concrete has been discharged. Do not obtain samples until after all of the pump slurry has been eliminated. Sample by repeatedly passing a receptacle through the entire discharge system or by completely diverting the discharge into a sample container. Do not lower or raise the pump arm from the placement position to ground level for ease of sampling, as it may modify the air content of the concrete being sampled. Do not obtain samples from the very first or last portions of the batch discharge. To reduce variability in air tests, ensure that the pump configuration is such that sufficient back pressure is achieved and a constant flow is being discharged before sample is obtained.

5. Sampling from Concrete Slab as Placed

Mark the approximate location of concrete placed on grade and sampled for air content. After the paver has passed the marked location, remove the sample from the slab, approximately in line with a vibrator and within an 18 in. x 18 in. square area to a depth approximately two-thirds of the pavement thickness. The sample should be obtained a minimum of 12 in. from the edge of slab to prevent extra handwork in maintaining the pavement edge.

Transport samples to the place where fresh concrete tests are to be performed and specimens are to be molded. Protect the sample from direct sunlight, wind, rain, and sources of contamination.

Complete test for temperature within five minutes of obtaining the sample. Start tests for slump and air content within five minutes of obtaining the sample. Complete tests as quickly as possible. Start molding specimens for strength tests within 15 minutes of obtaining the sample.
1. This method covers sampling from five types of mixers or placement systems, which are __________________, __________________, __________________, __________________, and ____________________.

2. When sampling from a ready mix truck how must the concrete be sampled during discharge of the batch?

3. The concrete sample must be protected from contamination, __________________, __________________, and ____________________.

4. Where do you get the sample from the slab?

5. What time limits are specified for testing after obtaining a sample?

6. How many sample locations are needed for concrete samples on the grade?
IM 385 - TEMPERATURE OF FRESHLY MIXED CONCRETE
CONCRETE TEMPERATURE

The temperature of fresh concrete is taken when it is placed. Hot and cold weather have effects on the concrete and the hydration process.

The temperature is normally monitored by the Iowa DOT. The temperature will give the indication if concrete may require special attention in the curing and protection areas. Concrete in cold weather must attain a minimum strength to be able to withstand one freeze/thaw cycle without cracking. Concrete must be cured properly to prevent plastic shrinkage cracking.

The temperature of the concrete must be taken properly to get an accurate reading. If the base of the thermometer is not properly covered the reading will be incorrect. During hot weather conditions, temperature of concrete may be the reason for high water/cement ratio, workability problems, and make it difficult to entrain air. Ice may be added in the water or night paving may be an option. During cold weather the temperature may contribute to slow strength gain and indicate a need for protection. Concrete hydrates best at 55°F. Temperatures below 40°F and above 90°F require attention with curing and protection.

IM 385 gives the proper procedure for testing the temperature on fresh concrete.
TEMPERATURE OF FRESHLY MIXED CONCRETE

SCOPEThis test method covers the determination of temperature of freshly mixed Portland Cement Concrete.

This standard may involve hazardous materials, operations, and equipment. This standard does not address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices.

SIGNIFICANCE & USEThis test method provides a means for measuring the temperature of freshly mixed concrete. It may be used to verify conformance to a specified requirement for temperature of concrete. For specification compliance, temperature shall be measured by means of an immersion temperature-measuring device. Infrared thermometers may be used for information purposes only.

PROCEDURE
A. Apparatus

1. Container. The container shall be made of nonabsorptive material and large enough to provide at least 3 in. (75 mm) of concrete in all directions around the sensor of the temperature-measuring device; the concrete cover shall also be at least three times the nominal maximum size of the coarse aggregate.

2. Temperature-measuring Device. The temperature-measuring device shall be capable of reading the temperature of the freshly mixed concrete to ±1°F (±0.5°C) throughout the entire temperature range likely to be encountered in the fresh concrete. Liquid-in-glass thermometers having a range of 0°F to 120°F (-18°C to 49°C) are satisfactory. Other thermometers of the required accuracy, including the metal immersion type, are acceptable.

3. Thermometer Marking. Partial-immersion liquid-in-glass thermometers (and possibly other types) shall have a permanent mark to which the device must be immersed without applying a correction factor.

4. Reference Temperature-measuring Device. The reference temperature-measuring device shall be a liquid-in-glass thermometer readable to 0.5°F (0.2°C) that has been verified and calibrated. The calibration certificate or report indicating conformance to ASTM E77 requirements shall be available for inspection. Other temperature-measuring devices may be used if the calibration is certified.

B. Calibration of Temperature-measuring Device

1. Each temperature-measuring device used for determining the temperature of freshly mixed concrete shall be calibrated before initial use, or whenever there is a question of
accuracy. This calibration shall be performed by comparing the readings on the temperature-measuring device at two temperatures at least 27°F (15°C) apart.

C. Sampling Concrete

1. The temperature of freshly mixed concrete may be measured in the transporting equipment providing the sensor of the temperature-measuring device has at least 3 in. (75 mm) of concrete cover in all directions around it.

2. If the transporting equipment is not used as the container, a sample shall be prepared as follows:
   a. Immediately prior to sampling the freshly mixed concrete, dampen (with water) the sample container.
   b. Sample the freshly mixed concrete in accordance with IM 327.
   c. Place the freshly mixed concrete into the container. (NOTE: When concrete contains a nominal maximum size of aggregate greater than 3 in. (75 mm), it may require 20 minutes after mixing before the temperature is stabilized.)
   d. Complete the temperature measurement of the freshly mixed concrete within five minutes after obtaining the sample.

D. Test Procedure

1. Place the temperature-measuring device in the freshly mixed concrete, so the temperature-sensing portion is submerged in a minimum of 3 in. (75 mm) of concrete. Gently press the concrete around the temperature-measuring device at the surface of the concrete so the ambient air temperature does not affect the reading.

2. Leave the temperature-measuring device in the freshly mixed concrete for a minimum period of two minutes or until the temperature reading stabilizes, then read and record the temperature.

3. Complete the temperature measurement of the freshly mixed concrete within five minutes of obtaining the sample.

4. Record the measured temperature of the freshly mixed concrete to the nearest 1°F (0.5°C).
1. Why is the temperature of concrete generally taken?

2. The temperature measuring device shall be calibrated ________________, or whenever there is a question of ________________.

3. Is an infrared temperature measuring device acceptable for taking concrete temperatures?

4. How soon after your sample is taken do you need to have the temperature test completed?
CONCRETE SLUMP

The slump of concrete is used to determine the consistency of the freshly mixed concrete. The slump test needs to be properly performed to determine if the concrete is within specification limits.

Contractors and agencies perform slump on structures, formed paving, patching, and other types of concrete pours as required per specification.

There are occasions when slump may be increased by adding Mid Range or High Range Water Reducers.

The slump test needs to be run in the specified time requirement or there is the possibility of an erroneous result. It must be started within 5 minutes of obtaining the sample. Proper consolidation of the concrete in the slump cone is necessary for correct measurements. Target slump is normally 3 inches. Normally when one gallon of water per cubic yard of concrete is added, the slump will increase approximately one inch.

IM 317 gives the proper procedure for performing a slump test. IM 204 specifies the testing frequencies.
SLUMP OF HYDRAULIC CEMENT CONCRETE

SCOPE

This procedure provides instructions for determining the slump of hydraulic cement concrete. It is not applicable to non-plastic or non-cohesive concrete, nor when the maximum size of the coarse aggregate is over 2 in.

SIGNIFICANCE

The slump test is used to determine the consistency of concrete. Consistency is a measure of the relative fluidity or mobility of the mixture. Slump does not measure the water content or workability of the concrete. While it is true that an increase or decrease in the water content will cause a corresponding increase or decrease in the slump of the concrete, many other factors can cause slump to change without any change to water content. One cannot assume that the water/cement ratio is being maintained simply because the slump is within specification limits.

PROCEDURE

A. Apparatus

1. Slump Cone. The slump cone shall conform to AASHTO T 119: The mold shall be provided with foot pieces and handles. The mold may be constructed either with or without a seam. The interior of the mold shall be relatively smooth and free from projections such as protruding rivets. The mold shall be free of dents. A mold that clamps to a rigid non-absorbent base plate is acceptable provided the clamping arrangement is such that it can be fully released without movement of the mold.

2. Tamping Rod. The tamping rod shall be 5/8 in. in diameter and approximately 24 in. in length, having a hemispherical tip.

3. Scoop.

4. Tape Measure or Ruler. These should have at least 1/8 in. gradations.

5. Base. The base shall be rigid with a non-absorbent surface on which to set the slump cone.

B. Test Procedure

1. Obtain the sample in accordance with IM 327.

2. Dampen the inside of the cone and place it on a dampened, rigid, non-absorbent surface that is level and firm.
3. Stand on both foot pieces in order to hold the mold firmly in place.

4. Fill the cone 1/3-full in volume, to a depth of 2 5/8 in. in depth.

5. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. For this bottom layer, incline the rod slightly and make approximately half the strokes near the perimeter, and then progress with vertical strokes, spiraling toward the center.

6. Fill the cone 2/3-full in volume, to a depth of 6 1/8 in. in depth.

7. Consolidate this layer with 25 strokes of the tamping rod, penetrating the bottom layer approximately 1 inch. Distribute the strokes evenly.

8. Fill the cone to overflowing.

9. Consolidate this layer with 25 strokes of the tamping rod, penetrating the second layer approximately 1 inch. Distribute the strokes evenly. If the concrete falls below the top of the cone, stop, add more concrete, and continue rodding for a total of 25 strokes. Keep an excess of concrete above the top of the mold at all times. Distribute strokes evenly as before.

10. Strike off the top surface of concrete with a screeding and rolling motion of the tamping rod.

11. Clean the overflow concrete away from the base of the mold.

12. Remove the mold from the concrete by raising it carefully in a vertical direction. Raise the mold 12 in. in 5 ± 2 seconds by a steady upward lift with no lateral or torsional motion being imparted to the concrete.

The entire operation from the start of the filling through removal of the mold shall be carried out without interruption and shall be completed within an elapsed time of 2 1/2 minutes.

13. Invert the slump cone and set it next to the specimen.

14. Lay the tamping rod across the mold so it is over the test specimen.

15. Measure the distance between the bottom of the rod and the displaced original center of the top of the specimen to the nearest 1/4 in.

**NOTE:** If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make a new test on another portion of the sample. If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks the plasticity and cohesiveness necessary for the slump test to be applicable.
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</table>
1. Describe the mold used for making the slump test.

2. The surface on which the slump cone will be placed must be ________________.

3. The approximate concrete depth (in inches) after placing the first layer is ________________ and the second layer is ________________.

4. When rodding the bottom layer, the tamping rod must be ________________ to uniformly distribute the strokes.

5. If, while rodding the top layer, the concrete drops below the top of the slump cone, what must be done?

6. The measurement for slump is made from the top of the mold to what point of the concrete specimen?

7. While the technician is checking the slump of the concrete, there is a decided falling away or shearing off of the concrete from one side of the sample. What should the technician do?

8. How soon after your sample is taken do you need to start the slump test?
Air tests are run on fresh concrete to determine the amount of entrained air in the concrete mixture. Proper test procedures are required so an accurate percentage of entrained air in the concrete can be determined and specifications are met.

Knowing the entrained air content is important on both structures and paving projects and is tested by both the contractor and agency. Adequate air content in concrete is necessary to provide freeze/thaw resistance for long term durability. Since concrete is porous, water will invade the pores and expand when frozen which will crack the concrete, without air voids to provide relief from the pressure of frozen water.

The concrete needs to be placed and consolidated in the air meter properly or the air reading could be erroneous. The air test must be started within 5 minutes of obtaining the sample.

It is important that the air meters are cleaned and calibrated:

- Annually
- Prior to use on a project
- Periodically throughout the construction season.
- When results don’t correlate

The air meter should be transported in the proper storage container to prevent damage to the gauge. The air meter should be kept clean and free of hardened concrete. Normally a 6% in place air content is required to provide the needed protection. Specifications require higher amounts to account for air loss due to vibration of the concrete. Normally a one percent increase in air content decreases compressive strength approximately 5%.

IM 318 gives the proper procedure for testing entrained air and calibration of the air meter. IM 204 specifies the testing frequencies.

There are aggregates that require an aggregate correction factor when tested using the Pressure Method. These aggregates are listed on page 7-8 of IM 318. When using any of these aggregates, contact the District Materials Engineer for the correction factor. When calculating air content according to IM 340, the correction factor isn’t required.
AIR CONTENT OF FRESHLY MIXED CONCRETE BY PRESSURE

SCOPE

This test method describes the procedure for determining the air content of freshly mixed concrete by one form of pressure method.

PROCEDURE

NOTE: Certain coarse aggregates in eastern Iowa with large interconnected pores in the aggregate will cause air meter readings to indicate higher air content than is actually in the concrete because air is compressed in the aggregate pores just as the air is compressed in the paste. An aggregate correction factor must be applied to correct the air content. AASHTO T152 requires an aggregate correction factor for all concrete; however, it typically is not large enough for most aggregates to require adjustment. A list of aggregates that typically require a correction factor is included as well as the procedure to determine aggregate correction factor.

A. Apparatus

1. Measure bowl and cover assembly: All apparatus used shall incorporate the requirements of AASHTO Designation T-152 Section 4, for a Type B Washington-type meter.

2. Tamping Rod: 5/8 in. diameter, having a hemispherical tip.

3. Scoop

4. Strike-off bar

5. Rubber mallet

6. Rubber syringe or polyethylene unitary wash bottle

B. Test Procedure (For use with Washington-Type Air Meter)

NOTE: All meters shall be calibrated annually. Check calibration prior to use on a project and periodically throughout the construction season.

1. Calibration of Apparatus

   Calibration Canisters (Plug method)

   The volume of the calibration canister should be 0.0125 ft³. The effective air volume of the canister depends on the volume of the air meter being calibrated.

   Effective Air Volume =100 X 0.0125 ft³/(air meter pot volume)

   Below is the effect air volume for the range of meters in service.

   Effective air volume
2. Calibration Plug Procedure

a. Fill the air meter with water. The water should be about the same temperature as the air temperature.
   Note: Many faucets will mix air into the water. This air can be enough to affect the calibration. In this case, the water should be drawn and left to sit for several hours.

b. Put the lid on and using a plastic bottle provided or a rubber syringe, inject water through one petcock until all the air is expelled through the opposite petcock. Jar the base to insure removal of all air. Leave petcocks open.

c. Stabilize the dial hand at proper initial pressure line by pumping or bleeding off, as needed, while lightly tapping the backside of the dial with the fingers. Inject water through the petcock again to make sure all the air is expelled.

d. Close both petcocks and press down on the thumb lever exhausting air into the base. The dial should read 0.0%. If the dial does not read 0.0%, the test should be repeated. If two or more tests are off by the same amount, a new initial pressure line should be established and the test repeated to confirm a 0.0% reading.

e. Open the petcocks to relieve the pressure and remove the lid.

f. Make sure the calibration canisters have no water inside and that the bottom hole is clear of debris. Place the canister in the water making sure not to release air from the canister. Repeat step b and c. Close both petcocks and press down on the thumb lever exhausting air into the base. While holding the lever, lightly tap the gage to stabilize the dial reading. The dial should read the effective air volume of the canister (5.0% for air meters with a 0.25 ft³ volume).

g. If the dial reading variation is +/- 0.2% or more from the effective air volume, repeat the test using 2 calibration canisters in the pot. If the dial reading variation is +/- 0.2% (+/-0.25% for dials with 0.5% graduations) or less from the effective air volume, the air meter is in proper calibration.
h. If the dial readings are beyond the tolerance for either or both air volumes, the test should be repeated. If after two or more tests, the variation is the same and/or beyond the tolerances, the air meter gauge needs adjustment or replacement. Adjustment of the air meter gauge should only be attempted by trained personnel. For DOT, county, and city owned air meters, the trained personnel include the District Materials staff and the Central Laboratory Testing Support Personnel.

See Iowa Test Method 405 for Water Method Calibration

3. Operation of Apparatus (Determination of Air Content of Concrete)

a. Fill the base with a sample of fresh concrete placing the concrete in the base in three equal layers. Rod each layer twenty-five times with the tamping rod provided with the meter. For slumps less than 1 in., the sample may need to be consolidated by internal vibration.

b. Do not allow the rod to forcibly strike the bottom of the base while rodding the bottom layer. For each upper layer, the rod shall penetrate 1 inch into the underlying layer. Care should also be taken to avoid hitting the top edge of the base with the tamping rod.

c. Tap the sides of the base 10-15 times with a rubber mallet after rodding each layer to close the holes left by the rod.

d. A clean, smooth surface on the top edge of the base is necessary to insure a tight seal with the cover. Strike off base, level full, with the straight edge furnished. Wipe the top edge of the base clean to insure a tight seal with the cover.

e. Clamp cover on with petcocks open.

f. With the built in pump, pump air into the air chamber atop the cover until the pressure indicator points to the proper initial pressure line on the gauge. **NOTE:** The pump stem may need a light coat of oil to slide freely. Too much oil on the stem will fill the pump chamber and block the air valve causing the pump to fail.

g. Using a rubber syringe, inject water through one petcock until all the air is expelled through the opposite petcock. Jar the base to insure removal of all air. Leave petcocks open. **NOTE:** Use care if injecting water through opposite petcock to not add air bubbles. When jarring the base to remove the air, the base shall not be tilted more than 2 inches from horizontal.

The sequence of Steps f. and g. may be interchanged without adversely affecting the test result.

i. Stabilize dial hand at the proper initial pressure line by pumping or bleeding off, as needed, while lightly tapping the backside of the dial with the fingers. Inject water through the petcock again to make sure all the air is expelled.

i. Close both petcocks. Press down on lever to release air into the base. Tap the sides of the measuring bowl with the rubber mallet to relieve local constraints. Hold lever down a few seconds lightly tapping the backside of the dial with your fingers until the dial stabilizes. Observe the dial reading before letting up on the lever. Record the dial
reading. Report the air content to the nearest 0.1% for air contents up to 8%, or the nearest 1/2 scale division at 8% or higher air content.

j. Open petcocks to release pressure, and then remove cover. Empty the concrete from base, clean up base, cover with petcocks left opened.

4. Determination of Aggregate Correction Factor
   a. The aggregate correction factor is determined independently by applying the calibrated pressure to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount and proportions occurring in the concrete sample under the test.
   
b. Calculate the sample weights of the fine and coarse aggregate as follows:

\[
F_s = (S/B) \times F_b
\]
\[
C_s = (S/B) \times C_b
\]

Where:
- \( F_s \) = weight of fine aggregate in concrete test sample, lb.
- \( S \) = volume of measuring bowl, ft\(^3\)
- \( B \) = volume of concrete produced per batch, ft\(^3\)
- \( F_b \) = weight of fine aggregate in the moisture condition used in batch, lb.
- \( C_s \) = weight of coarse aggregate in concrete sample under test, lb.
- \( C_b \) = weight of coarse aggregate in the moisture condition used in batch, lb.

Example of C-3WR Mix

Coarse aggregate wet batch weight = 1597
Fine aggregate wet batch weight = 1421
Container volume = 0.248 ft\(^3\)

Coarse Aggregate Weight \( (C_s) \) = \( (0.248/27) \times 1597 = 14.67 \) lbs. (6653 grams)
Fine Aggregate Weight \( (F_s) \) = \( (0.248/27) \times 1421 = 13.05 \) lbs. (5920 grams)

c. Mix representative samples of the coarse and fine aggregate, and place in a measuring bowl one-third full of water. Add the mixed aggregate to the bowl, introducing each scoopful in a manner which minimizes entrapped air. If necessary, add additional water to inundate the aggregate. Stir, rod and tap the sides of the bowl to eliminate entrapped air.

d. Soak the aggregate for a time period approximately equal to the amount of time between the introduction of the water into the mixer and the time of performing the test for air content.

e. Follow steps e, f, g, h, and i in paragraph 3. Operation of Apparatus

f. The air content reading is the aggregate correction factor. For ease of determining plastic concrete air in the field, the aggregate correction factor will be rounded down to the nearest 0.5%.

g. Actual concrete air content = Air meter reading - Aggregate correction factor
NOTE: If performing test by removal of a measured amount of water, the inside calibration tube may need to be cut short to prevent drawing sand into the water. When using this method the aggregate correction factor will be the air content reading minus volume of water removed expressed as percent volume of the bowl.

Air Meter and Calibrating Accessories
NOTE: The following is a list of aggregate sources, including bed numbers, that will typically need an aggregate correction factor applied. When these aggregates are used without an aggregate correction factor applied, excessive bleeding is commonly noted, especially on bridge decks. There is a fairly good correlation of aggregate sources with an Iowa Pore Index primary load greater than 100 may require an aggregate correction factor. Contact the District Materials Engineer when using these aggregates.

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<thead>
<tr>
<th>Source #</th>
<th>Name</th>
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<tbody>
<tr>
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<td>A09006</td>
<td>Tripoli Platte</td>
<td>1-5</td>
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<tr>
<td>A10010</td>
<td>Hazelton</td>
<td>4</td>
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<td>A10030</td>
<td>S. Aurora</td>
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<td>A16006</td>
<td>Stonemill</td>
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<td>Shaffton</td>
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Air and Slump Tests

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<th>Air (%)</th>
<th>Slump (In)</th>
<th>Application</th>
<th>Remarks</th>
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Review Questions
Air Content of Freshly Mixed Concrete by the Pressure Method
IM 318

1. How many times is each layer of concrete rodded?

2. What care should be taken when rodding each layer?

3. After rodding each layer, what should be done to the measure before adding another layer of concrete?

4. How soon after your sample is taken do you need to start the air test?
UNIT WEIGHT, YIELD, and AIR OF CONCRETE

The unit weight of concrete is determined to give an indication of problems in batch weights and yield. Air content can also be determined by performing a unit weight test.

A unit weight test can be performed by both contractors and agencies to assist in determining if the batch weights need to be adjusted due to incorrect yields. This test is not used in the acceptance of concrete, only for information purposes.

The air meter base is used in the test to determine unit weight. The concrete needs to be consolidated and struck off properly. There can be no concrete on the sides of the air meter base since the weight of the concrete and base is determined and must be accurate or results will be affected. Air content can also be determined by running this test and could be used if correlation problems are occurring.

IM 340 explains the proper procedure and calculations for determining unit weight, yield, and air content.
WEIGHT PER CUBIC FOOT, YIELD & AIR CONTENT (GRAVIMETRIC) OF CONCRETE

SCOPE
This procedure covers the determination of density, or unit weight of freshly mixed concrete. It also provides formulas for calculating the volume of concrete produced from a mixture of known quantities of component materials.

SIGNIFICANCE
The unit weight is a useful tool in determining the concrete batch yield and air content. Since air adds no weight to the concrete and only occupies a volume, the unit weight of the concrete gives a very good indication of the air content of the concrete. Normal weight concrete is in the range of 140 - 150 lbs./cu. ft. For normal weight concrete, a change in unit weight of 1.5 lbs./cu. ft. relates to approximately a 1 percent change in air content. Using the unit weight to indicate air content can also prevent any discrepancies between air meters.

PROCEDURE
A. Apparatus

1. Measure: May be the base of the air meter used for determining air content from IM 318. Otherwise, it shall be a metal container meeting the requirements of AASHTO T-121. The capacity and dimensions of the measure shall conform to those specified in Table 1.

2. Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use.

3. Tamping Rod: 5/8 in. diameter, having a hemispherical tip.

4. Vibrator: 7000 vibrations per minute, 0.75 in. to 1.50 in. in diameter, at least 3 in. longer than the section being vibrated for use with low slump concrete.

5. Scoop

6. Strike off bar

7. A glass or acrylic strike off plate at least 1/2 in. thick, with a length and width at least 2 in. greater than the diameter of the measure. The edges of the plate shall be straight and smooth within tolerance of 1/16 in.

8. Rubber Mallet

Table 1 - Dimensions of Measures

<table>
<thead>
<tr>
<th>Capacity (ft.³)</th>
<th>Inside Diameter (in.)</th>
<th>Inside Height (in.)</th>
<th>Minimum Thickness (in.) Bottom Wall</th>
<th>Nominal Maximum Size of Coarse Aggr. (in.)</th>
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</thead>
<tbody>
<tr>
<td>1/4</td>
<td>8.0 ± 0.1</td>
<td>8.4 ± 0.1</td>
<td>0.20</td>
<td>0.12</td>
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</tbody>
</table>
Measure may be the base of the air meter used in IM 318.

B. Calibration of Measuring Bowl

1. Determine the weight of the dry measure and strike-off plate.

2. Fill the measure with water at a temperature between 60ºF and 85ºF and cover with the strike-off plate in such a way as to eliminate bubbles and excess water.

3. Wipe dry the measure and cover plate, being careful not to lose any water from the measure.

4. Determine the weight of the measure, strike-off plate, and water in the measure.

5. Determine the weight of the water in the measure by subtracting the weight in Step 1 from the weight in Step 4.

6. Measure the temperature of the water and determine its density from Table 2, interpolating as necessary.

7. Calculate the volume of the measure, \( V_m \), by dividing the weight of the water in the measure by the density of the water at the measured temperature, from Table 2.

\[
V_m = \frac{\text{weight of water}}{\text{density of water}}
\]

Example:

\[
V_m = \frac{15.57}{62.274} \quad V_m = 0.250 \text{ ft.}^3
\]

<table>
<thead>
<tr>
<th>ºF</th>
<th>lb./ft.³</th>
<th>ºF</th>
<th>lb./ft.³</th>
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</thead>
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<td>76.0</td>
<td>62.252</td>
<td>85.0</td>
<td>62.166</td>
</tr>
</tbody>
</table>

C. Testing Procedure

**NOTE:** There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 3 in., consolidation is by rodding. When the slump is 1 to 3 in., internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency in order to obtain consistent, comparable results. For slumps less than 1 in., the sample may be consolidated by internal vibration.

1. Determine the weight of the dry measure.
2. Obtain the sample in accordance with IM 327. Testing may be performed in conjunction with IM 318. When doing so, this test should be performed prior to IM 318. **NOTE:** If the two tests are being performed using the same sample, this test shall begin within five minutes of obtaining the sample.

3. Dampen the inside of the measure.

4. Fill the measure approximately 1/3-full with concrete.

5. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.

6. Tap the sides of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.

7. Add the second layer, filling the measure about 2/3-full.

8. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in. (25 mm) into the bottom layer.

9. Tap the sides of the measure smartly 10 to 15 times with the mallet.

10. Add the final layer, slightly overfilling the measure.

11. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in. (25 mm) into the second layer.

12. Tap the sides of the measure smartly 10 to 15 times with the mallet.

**NOTE:** The measure should be slightly over full, about 1/8 in. (3 mm) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.

13. Strike off the surface of the concrete and finish it smoothly with a screening action of the strike off bar (sawing action of the strike-off plate) using great care to leave the pot just full. The surface should be smooth and free of voids.

14. Clean off all excess concrete from the exterior of the measure including the rim.

15. Determine and record the weight of the measure and the concrete.

16. If the air content of the concrete is to be determined, proceed to Step 3. e of IM 318.

D. Calculations

**Unit Weight (density)** – Calculate the net weight, \( W_3 \), of the concrete in the measure by subtracting the weight of the measure, \( W_2 \), from the gross weight of the measure plus the
concrete, $W_3$. Calculate the density, $\rho$, by dividing the net weight, $W_3$, by the volume, $V_m$, of the measure as shown below.

$$W_1 - W_2 = W_3 \quad \text{Example: } 42.8 - 7.6 = 35.2 \text{ lb.}$$

$$\rho = \frac{W_3}{V_m} \quad \text{Example: } \rho = \frac{35.2 \text{ lb.}}{0.249 \text{ cu. ft.}} = 141.37/\text{cu. ft.}$$

Theoretical unit weight (air-free basis) – The theoretical unit weight, $T$, is the total weight of materials batched divided by the absolute volume of materials batched on an air-free basis.

Using the actual batch weights and absolute volumes, sum the following:

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Cement</td>
<td>477</td>
<td>3.14</td>
<td>0.090</td>
<td>= 477/(3.14 x 62.4 x 27)</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>84</td>
<td>2.68</td>
<td>0.019</td>
<td></td>
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<tr>
<td>Total Water</td>
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<td>1.00</td>
<td>0.131</td>
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</tbody>
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<table>
<thead>
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<th>Aggregate, SSD Dry Batch Weights</th>
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</thead>
<tbody>
<tr>
<td>Fine</td>
</tr>
<tr>
<td>Intermediate</td>
</tr>
<tr>
<td>Coarse</td>
</tr>
</tbody>
</table>

Total 3842 0.938

Theoretical unit weight (cu. Ft.) = \( \frac{\text{Batch weight}}{\text{Abs. Vol. x 27}} \)

\[
= \frac{3842}{0.938 \times 27} = 151.7 \text{ lbs./cu. ft.}
\]

Air Content – Air content is calculated by subtracting the unit weight, $\rho$, from the theoretical unit weight, $T$, divided by the theoretical unit weight, $T$, multiplied by 100 as shown below.

$$A = \frac{T - \rho}{T} \times 100$$

Example: \( A = \frac{151.7 \text{ lbs./cu. ft} - 141.37 \text{ lbs./cu. ft}}{151.7 \text{ lbs./cu. ft}} \times 100 = 6.8\% \)

Theoretical Unit Weight = 151.7 lbs./cu. ft.

The theoretical unit weight, $T$, is the total weight of materials batched divided by the absolute volume of materials batched on an air free basis.
Relative Batch Yield – Calculate the yield, \( Y \), or volume of concrete produced per cubic yard, by dividing the total weight of the cubic yard batched, \( W_t \), by 27, then dividing by the density, \( \rho \), of the concrete as shown below.

\[
Y = \frac{W_t \div 27}{\rho}
\]

**Example:**
\[
Y = \frac{3842 \text{ lbs. batched per cu. yd.} \div 27}{141.37 \text{ lb./cu. ft.}} = 1.007
\]

E. Density of Foamed Cellular Concrete

Foamed cellular concrete density may be determined as above using a smaller 1/10 cubic foot measure, or using a 400 ml cup and the following procedure.

1. Apparatus
   a. Measure: A cylindrical measure meeting the requirements of ASTM C 185. Otherwise, any cylindrical container of a known volume, made of steel or other suitable metal container, not readily attacked by Portland cement.
   b. Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use.
   c. Scoop or spoon
   d. A strike off bar
   e. A metal or glass plate at least 1/4 in. thick, with a length and width at least 1 in. greater than the diameter of the measure.

2. Testing Procedure
   a. Determine the weight of the dry measure. Include the glass plate when using the 400 ml cup
   b. Obtain the sample of the foamed concrete. Testing shall begin within five minutes of obtaining the sample.
   c. Dampen the inside of the measure.
   d. Fill the measure in one layer, slightly overfilling the measure. Do not strike sides of measure. An excess of concrete protruding approximately 3 mm [1/8 in.] above the top of the mold is optimum.
   e. Strike off the surface of the concrete and finish it smoothly with a screening action of the strike off bar (sawing action of the strike-off plate) using great
care to leave the pot just full. The surface should be smooth and free of voids.

f. Press the glass plate down on the surface of the concrete to ensure the surface free of voids. Clean off all excess concrete from the exterior of the measure including the bottom of the plate. Determine and record the weight of the measure, plate, and concrete.

3. Calculations

\[
\begin{align*}
\text{Wt Cup + Plate + Conc. (gms)} &= 1069.00 \\
\text{Wt. Mortar Cup + Plate (gms)} &= 741.50 \\
\text{Weight of Concrete (gms)} &= 327.50 \\
\text{Volume of 400 ml container (l)} &= 0.400 \\
\text{Actual Unit Weight} &= \frac{327.50}{0.400} = 818.75 \text{ kg/m}^3
\end{align*}
\]

Convert kg/m\(^3\) to lb/ft\(^3\)
\[
818.75 \text{ kg/m}^3 / 16.0185 \text{ kg/m}^3 /\text{lb/ft}^3 = 51.1 \text{ lb/ft}^3
\]
1. Why is the unit weight of concrete determined?

2. What is the required shape of the tamping end of the rod?

3. After completing the strike-off procedure, what must be done before determining the weight of the measure and sample?

4. What is the weight range for a cubic foot of normal weight concrete?
### Unit Weight

**Equation as shown in IM 340:**

\[
\rho = \frac{W_3}{V_m}
\]

Where \(W_3 = W_1 - W_2\)

**Or in other words:**

\[
\text{Unit Weight} = \frac{\text{Weight of Pot & Concrete} - \text{Weight of Empty Pot}}{\text{Volume of Pot}}
\]

**Example:**

- Weight of the air pot filled with concrete: 43.6 lbs
- Weight of the empty air pot: 8.1 lbs
- Volume of the air pot: 0.248 ft³

\[
\text{Unit Weight} = \frac{43.6 \text{ lbs} - 8.1 \text{ lbs}}{0.248 \text{ ft}^3} = 143.15 \frac{\text{lbs}}{\text{ft}^3}
\]

### Yield

**Equation as shown in IM 340:**

\[
Y = \frac{W_t + 27}{\rho}
\]

**Or in other words:**

\[
\text{Yield} = \frac{\text{Weight of the batched concrete per cubic yard}}{\text{Unit Weight}} + \frac{27}{\text{yd}^3}
\]

**Example Continued:**

- Total weight of the batched concrete on the truck: 27,475 lbs
- Total cubic yards of batched concrete on the truck: 7 yd³

\[
\text{Yield} = \frac{3925 \frac{\text{lb}}{\text{yd}^3} + 27 \frac{\text{ft}^3}{\text{yd}^3}}{143.15 \frac{\text{lb}}{\text{ft}^3}} = \frac{145.37}{143.15} = 1.015
\]

### Air Content

**Equation as shown in IM 340:**

\[
A = \frac{T - \rho}{T} \times 100
\]

**Or in other words:**

\[
\text{Air Content} = \frac{\text{Maximum Theoretical Weight} - \text{Unit Weight}}{\text{Maximum Theoretical Weight}} \times 100
\]

**Example Continued:**

- Maximum Theoretical Unit Weight from the concrete plant: 151.10 \frac{\text{lbs}}{\text{ft}^3}

\[
\text{Air Content} = \frac{151.10 \frac{\text{lb}}{\text{ft}^3} - 143.15 \frac{\text{lb}}{\text{ft}^3}}{151.10 \frac{\text{lb}}{\text{ft}^3}} \times 100 = \frac{7.95}{151.10} \times 100 = 5.3
\]
Unit Weight, Yield and Air
Problem #1

Given the following information, calculate Unit Weight, Yield and Air Content:

- Weight of the air pot filled with concrete: 87.5 lbs
- Weight of the empty air pot: 16.4 lbs
- Volume of the air pot: 0.496 ft³
- Total weight of the batched concrete on the truck: 24,086 lbs
- Total cubic yards of batched concrete on the truck: 6 yd³
- Maximum Theoretical Unit Weight from the concrete plant: \(151.50 \frac{\text{lbs}}{\text{ft}^3}\)

\[
\text{Unit Weight} = \frac{\text{Weight of Pot & Concrete} - \text{Weight of Empty Pot}}{\text{Volume of Pot}}
\]

\[
\text{Yield} = \frac{\text{Weight of the batched concrete per cubic yard}}{\text{Unit Weight}} \div 27 \frac{\text{ft}^3}{\text{yd}^3}
\]

\[
\text{Air Content} = \frac{\text{Maximum Theoretical Weight} - \text{Unit Weight}}{\text{Maximum Theoretical Weight}} \times 100
\]
Unit Weight, Yield and Air
Problem #2

Given the following information, calculate Unit Weight, Yield and Air Content:

- Weight of the air pot filled with concrete: 44.0 lbs
- Weight of the empty air pot: 7.7 lbs
- Volume of the air pot: 0.250 ft³
- Total weight of the batched concrete on the truck: 19,407 lbs
- Total cubic yards of batched concrete on the truck: 5 yd³
- Maximum Theoretical Unit Weight from the concrete plant: \( 150.70 \text{ lbs/ft}^3 \)

Unit Weight = \( \frac{\text{Weight of Pot & Concrete} - \text{Weight of Empty Pot}}{\text{Volume of Pot}} \)

\[
\text{Unit Weight} = \frac{44.0 \text{ lbs} - 7.7 \text{ lbs}}{0.250 \text{ ft}^3}
\]

\[
\text{Yield} = \frac{\text{Weight of the batched concrete per cubic yard ÷ 27 ft}^3}{\text{Unit Weight}} \text{ yd}^3
\]

Air Content = \( \frac{\text{Maximum Theoretical Weight} - \text{Unit Weight}}{\text{Maximum Theoretical Weight}} \times 100 \% \)
Concrete beams are used to determine the flexural strength of concrete. Beams need to be properly molded to ensure the strength of the concrete is correctly determined.

Concrete beams are used by contractors and agencies on structures and paving projects. Concrete beams are also used in the development of the maturity curve for projects where maturity testing is used for opening strengths.

Start molding specimens for strength test within 15 minutes of obtaining the sample. The concrete beam needs to be properly consolidated to remove voids in the concrete, which will reduce strength. The molded beam must be handled carefully when moving or transporting. They can not be allowed to move around in the back of the vehicle and need to protected against any impact. Beams should be protected when being transferred by wrapping in wet burlap and plastic to prevent moisture loss. It is important the beam is stored properly and kept moist until breaking. Moisture loss will cause lower strength. If the beam is not properly protected hot or cold weather will affect the strength.

IM 328 explains the proper procedure for making and curing concrete beams. IM 204 specifies the testing frequencies.
MAKING, PROTECTING & CURING
CONCRETE FLEXURAL STRENGTH FIELD SPECIMENS

SCOPE
This method covers procedures for making, protecting and curing flexural strength field specimens sampled from concrete being used in construction.

PROCEDURE

A. Apparatus

1. 6 in. x 6 in. x 20 in. minimum length or 4 in. x 4 in. x 14 in. minimum length beam mold. The molds provided will comply with the requirements of AASHTO T-23 for dimensions, construction, materials, smoothness and straightness.

2. Shovel (square point).

3. Rubber hammer or equivalent

4. Wood float or equivalent.

B. Test Procedure

Specimens molded for determination of compliance with strength specifications shall be cast and cured according to AASHTO T-23.

1. Secure the concrete sample in accordance with IM 327, Method of Sampling Concrete for Slump, Air Content and Strength Testing. Specimens shall be molded on a level, rigid, horizontal surface as near as practicable to the place where they will be stored during the first 20 ± 4 hours. All jarring, striking, tilting or scarring (however, preliminary markings with a nail or other sharp object within 4 in. of the beam end will be permitted) of the specimen surface shall be avoided if moving immediately after striking off is necessary. Place the concrete in the mold in two equal layers and thoroughly spade each layer with the shovel. Use special care consolidating the sides and after spading each layer strike the sides of the form with a rubber hammer or equivalent until the spading marks are closed. Strike off the excess concrete and smooth the surface with as little manipulation of the concrete as possible. Excessive spading and smoothing must be avoided. Spading may be used for six inch beams only.

When consolidating by vibration, fill concrete in one layer. Insert the vibrator at intervals not exceeding 6 in. along the centerline of the long dimension of the specimen, avoiding the exact center of the beam. Sufficient vibration is achieved as soon as the surface has become relatively smooth. Avoid overvibration which may cause segregation. After vibrating, strike the sides of the form with a rubber hammer 10 to 15 times to release any air bubbles that may have been trapped.

When consolidating by rodding, specimens shall receive the proper number of roddings
evenly distributed per layer as indicated in the table, or one per 2 in$^2$ of surface area. The bottom layer shall be rodded throughout its depth. For the upper layer, the rod shall penetrate 1 in. into the underlying layer. After rodding each layer, strike the sides of the form with a rubber hammer 10 to 15 times to release any air bubbles that may have been trapped.

<table>
<thead>
<tr>
<th>Beam Mold</th>
<th>Rod Size</th>
<th>No. of Layers</th>
<th>No. of Roddings per Layer</th>
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</thead>
<tbody>
<tr>
<td>4 x 4 x 14</td>
<td>3/8 in.</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>6 x 6 x 20 in.</td>
<td>5/8 in.</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>6 x 6 x 22 in.</td>
<td>5/8 in.</td>
<td>2</td>
<td>66</td>
</tr>
</tbody>
</table>

2. Immediately after smoothing protect the freshly made beam against moisture loss by evaporation, against rapid temperature increase caused by the combined effects of hot weather, bright sun, and the chemical hydration process and against freezing or near freezing temperature. It is generally practical to apply the same protection to the test specimen that is applied to the represented pavement or structure. This is not absolutely necessary, however, so long as the three conditions outlined above are satisfied.

3. On the day after the specimens are made and when they have reached an age of 16 to 24 hours, move the specimens while still in the molds to the location of final storage and curing, generally the concrete plant inspector's laboratory. The beams, even with the molds in place, must be handled carefully to avoid injury. A slight jar or bump may cause cracking which may be invisible at the time but which may become apparent with later handling or as premature failure during testing.

4. Remove the specimens from the molds (generally at the plant), clean, oil, reassemble and return the molds to the sampling location (generally at the direction of the paving or grade inspector).

5. Assign a chronological number, which corresponds with the day the beam was made to each beam. Begin with number 1. When more than one beam is made on a given day use capital letters A, B, C, etc., following the number which identifies the day to identify the daily making sequence. When two or more mixers are operated on separate sections of a project use a separate letter identification preceding the number assigned to the beams made from each respective mixer. Clean the beam and mark the numbers on the smooth bottom of the beam as cast. The numbers should be neatly made, and should be 4 to 8 inches from the end of the beam.

6. Store the specimens in a wetted sand filled pit of adequate size to accommodate all specimens made on the project or in lime saturated water. A pit 4' x 6' x 18" is normally adequate. Place the specimens on a reasonable smooth bed of sand and cover them completely with additional sand. If the temperature in the sand-filled pit drops below 40°F remove the specimens and place them under wetted burlap in a heated enclosure or in lime saturated water. Maintain the specimens in a continually wet condition, and above 40°F until they are tested. **NOTE**: Lime-saturated water is prepared by mixing 0.4 ounces of hydrated lime with 1 gallon of water. Hydrated lime should be a minimum of 90 percent calcium hydroxide (CaOH).
Concrete Beam Molds
Review Questions
Making, Protecting, and Curing
Concrete Flexural Strength Field Specimens
IM 328

1. What size mold(s) can be used to make flexural strength specimens?

2. Immediately after smoothing the beam, it needs to be protected from what?
   1. 
   2. 
   3. 

3. At what age do the beams need to be so they can be moved to storage?

4. How should the specimens be maintained until they are tested?

5. How soon after your sample is taken do you need to start molding specimens for strength testing?
IM316 - TESTING
FLEXURAL SPECIMENS
TESTING FLEXURAL SPECIMENS (CONCRETE BEAMS)

Center-Point Loading

Flexural specimens referred to as concrete beams are used to determine the flexural strength of concrete. Beams need to be tested properly to ensure the strength of the concrete is correctly determined.

Contractors and agencies on structures and paving projects use concrete beams. Concrete beams are also used in the development of the maturity curve for projects where maturity testing is used for opening strengths.

When testing concrete beams always ensure that the proper loading rate is used. It is important to remember to keep beams moist until they are tested. Beams need to be measured correctly and placed in the beam testing machine properly or the strength reading will not be accurate. The strength for flexural specimens is measured in pounds per square inch (psi).

IM 316 explains the proper method for testing flexural specimens. IM 204 specifies the testing frequencies.

Third-Point Loading

Flexural Specimens are tested by third-point loading procedures for QMC and FAA projects. The test method for third-point loading is AASHTO Designation T 97-97 and ASTM Designation C 78-94. When the project requires third-point loading refer to the above Designation for correct testing procedures.
FLEXURAL STRENGTH OF CONCRETE

SCOPE

This test method is used for determining the flexural strength of concrete by the use of a simple beam with center-point loading.

PROCEDURE

A. Apparatus

1. Hydraulic testing machines provided on Portland Cement Concrete paving projects shall conform to AASHTO T-177. The hydraulic machine consists of a frame to hold the specimen, a hand-operated hydraulic jack, and a pressure gauge to read the load. Practically all of the hydraulic machines have a micro pump in the loading line to facilitate control of the last half of the load within specifications, and without pause in loading. A calibration sheet is included with each machine of this type. Additional equipment needed includes a caliper, plastic ruler and a tri-square. The hydraulic test machine needs to be calibrated annually by the DOT Central Laboratory. Calibration sheets with each machine will indicate the date last calibrated.

B. Test Specimen

1. The test specimen shall have approximate dimensions of 6 in. x 6 in. x 20 in. minimum length or 4 in. x 4 in. x 14 in. minimum length. The test specimen shall be kept wet until the time of the test.

C. Test Procedure

1. Rotate the beam on its side with finished side facing out and the bottom of the beam as placed in the machine will be the side of the beam as cast. A reference line may be drawn centered across the top as cast side to help center the beam in the testing machine.

2. Insert the stirrup pins in the slots at the bottom of the stirrups to prevent the stirrups from swinging while the beam is being placed in the machine. This also assures that the support bearings are in the correct position.

3. Place the beam in the testing machine so that the reference line on the as cast top side of the beam is directly under the centerline of the center bearing. The maximum fiber stress during application of the load will occur in the outer fiber across the bottom of the beam directly under the load.

4. Rotate the micro pump handle counter-clockwise to expose the maximum number of threads, and close the loading valve on the pump.

5. Apply a small initial load, and remove the stirrup pins.
6. The load may be applied rapidly up to approximately 50 percent of the estimated breaking load with the pump handle. The final half of the loading is accomplished by turning the crank of the micro pump, at a rate that the extreme fiber stress does not exceed 150 psi per minute. This is approximately 1200 pounds per minute on the test gauge for six inch beams and approximately 500 pounds per minute for four inch beams.

7. Using one of the fractured faces, take one measurement at each edge and one at the center of the cross section for each direction (width and depth). Make measurements to the nearest 0.05 in.. Average the three readings to determine the average width and average depth of the specimen at the section of failure. (Figure 1)

D. Calculations

1. From the calibration sheet furnished with each machine, determine the corrected load placed upon the beam. The machine should be calibrated annually.

2. Calculate the modulus of rupture as follows:

\[ R = \frac{3Pl}{2bd^2} \]

Where:

- \( R \) = Modulus of rupture, MPa or psi.
- \( P \) = Corrected load indicated, N or lb.
- \( l \) = Span length, mm or in., between supports (12 in. (4x4) or 18 in. (6x6))
- \( b \) = Width of beam at point of fracture, mm or in.
- \( d \) = Depth of beam at point of fracture, mm or in.

The modulus of rupture may also be calculated by using the coefficients in Figure 3 or 4. and the following formula:

\[ R \text{ (psi)} = P \text{ (lbs)} \times \text{Coefficient (1/in}^2)\text{).} \]

3. The typical range of modulus of rupture should be from 300 psi to 700 psi. Report the modulus of rupture to the nearest 5 psi.

E. The following figure shows the beam as it should be placed in the flexural testing machine, with the finished top as casted turned on its side.
Figure 1

Figure 2. Six Inch Concrete Specimen in Hydraulic Testing Machine
Figure 3. Hydraulic Testing Machine for Testing Four Inch Beams

F. Precautions - Always make sure the pointers on the gauge are set at zero before any loading begins.

Concrete Beam Coefficients - US Units

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<td>0.119936</td>
<td>0.118953</td>
<td>0.117986</td>
</tr>
<tr>
<td>6.15</td>
<td>0.123079</td>
<td>0.122027</td>
<td>0.120993</td>
<td>0.119977</td>
<td>0.118977</td>
<td>0.117994</td>
<td>0.117026</td>
<td>0.116075</td>
</tr>
<tr>
<td>6.20</td>
<td>0.121102</td>
<td>0.120067</td>
<td>0.119050</td>
<td>0.118049</td>
<td>0.117066</td>
<td>0.116098</td>
<td>0.115146</td>
<td>0.114210</td>
</tr>
</tbody>
</table>

Modulus of Rupture = Total Load X Coefficient
R (psi) = P (lbs.) X Coefficient (in-2)

Figure 4. Concrete Beam (6 in. x 6 in.) Coefficients
### Concrete Beam Coefficients - US Units

<table>
<thead>
<tr>
<th>Depth (in.)</th>
<th>3.80</th>
<th>3.85</th>
<th>3.90</th>
<th>3.95</th>
<th>4.00</th>
<th>4.05</th>
<th>4.10</th>
<th>4.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.80</td>
<td>0.328036</td>
<td>0.323776</td>
<td>0.319625</td>
<td>0.315579</td>
<td>0.311634</td>
<td>0.307787</td>
<td>0.304034</td>
<td>0.300370</td>
</tr>
<tr>
<td>3.85</td>
<td>0.319571</td>
<td>0.315421</td>
<td>0.311377</td>
<td>0.307435</td>
<td>0.303593</td>
<td>0.299844</td>
<td>0.296188</td>
<td>0.292619</td>
</tr>
<tr>
<td>3.90</td>
<td>0.311429</td>
<td>0.307385</td>
<td>0.303444</td>
<td>0.299603</td>
<td>0.295858</td>
<td>0.292205</td>
<td>0.288642</td>
<td>0.285164</td>
</tr>
<tr>
<td>3.95</td>
<td>0.303595</td>
<td>0.299652</td>
<td>0.295811</td>
<td>0.292066</td>
<td>0.288415</td>
<td>0.284855</td>
<td>0.281381</td>
<td>0.277991</td>
</tr>
<tr>
<td>4.00</td>
<td>0.296053</td>
<td>0.292208</td>
<td>0.288462</td>
<td>0.284810</td>
<td>0.281250</td>
<td>0.277778</td>
<td>0.274390</td>
<td>0.271084</td>
</tr>
<tr>
<td>4.05</td>
<td>0.288788</td>
<td>0.285037</td>
<td>0.281383</td>
<td>0.277821</td>
<td>0.274348</td>
<td>0.270961</td>
<td>0.267657</td>
<td>0.264432</td>
</tr>
<tr>
<td>4.10</td>
<td>0.281787</td>
<td>0.278128</td>
<td>0.274562</td>
<td>0.271006</td>
<td>0.267698</td>
<td>0.264393</td>
<td>0.261169</td>
<td>0.258022</td>
</tr>
<tr>
<td>4.15</td>
<td>0.275038</td>
<td>0.271466</td>
<td>0.267986</td>
<td>0.264594</td>
<td>0.261286</td>
<td>0.258060</td>
<td>0.254913</td>
<td>0.251842</td>
</tr>
<tr>
<td>4.20</td>
<td>0.268528</td>
<td>0.265041</td>
<td>0.261643</td>
<td>0.258331</td>
<td>0.255102</td>
<td>0.251953</td>
<td>0.248880</td>
<td>0.245881</td>
</tr>
</tbody>
</table>

*Modulus of Rupture = Total Load X Coefficient
R (psi) = P (lbs.) X Coefficient (in-2)*

**Figure 5.** Concrete Beam (4 in. x 4 in.) Coefficients
<table>
<thead>
<tr>
<th>Lab No.</th>
<th>Senders No.</th>
<th>Date Made</th>
<th>Beam No.</th>
<th>% Air Content ASTM C-231</th>
<th>Slump ASTM C-143 (in.)</th>
<th>w/c</th>
<th>Date Tested</th>
<th>Age (days)</th>
<th>Width (in.)</th>
<th>Depth (in.)</th>
<th>Total Load (lbs)</th>
<th>Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

**REMARKS**

* POOR CONSOLIDATION

Tested in accordance with ASTM C-78

Signed ______________________
Review Questions
Flexural Strength of Concrete
Using Simple Beam with Center-Point Loading
IM 316

1. The top of the beam as cast will be __________________ when placed in the machine.

2. The load may be applied rapidly up to approximately what percent of the estimated breaking load?

3. On the final half of the loading, the crank should be turned not to exceed how many pounds per minute on the test gauge?
   
   A: 4" Beam ______________

   B: 6" Beam ______________
Calculate the modulus of rupture as follows:

\[ R = \frac{3PL}{2bd^2} \]

Where:
- \( R \) = Modulus of rupture in lb./in.\(^2\), or megapascals
- \( P \) = Maximum applied load indicated in lb., or newtons
- \( l \) = Span length in inches, or millimeters between supports
- \( b \) = Width of beam in inches, or millimeters
- \( d \) = Depth of beam in inches, or millimeters

\[ P = 4800 \]

\[ R = \frac{3 \times 4800 \times 18}{2 \times 6.00 \times 5.80^2} = \frac{259200}{403.68} = 642 \text{ psi} \]

Using coefficient from table: \( 4800 \times 0.133769 = 642 \text{ psi} \)

Using the following information, determine modulus of rupture.

**Given:**

1. Width of beam = 6.10
   Depth of beam = 6.05
   Actual load = 5020

2. Width of beam = 6.00
   Depth of beam = 6.05
   Actual load = 4810

3. Width of beam = 4.05
   Depth of beam = 4.00
   Actual load = 2500

4. Width of beam = 4.05
   Depth of beam = 4.05
   Actual load = 2340
Concrete cylinders are used to determine the compressive strength of concrete. Cylinders need to be properly molded, cured, and tested to ensure the strength of the concrete is correctly determined.

The contractor in prestress/precast plants and for High Performance Concrete (HPC) projects uses concrete cylinders. The strength of a cylinder is tested to determine when a prestressed unit reaches specified strength to remove forms, move, or ship. The Iowa DOT uses concrete cylinders for informational purposes on structures and as acceptance on HPC.

The cylinder needs to be properly consolidated to remove entrapped air and voids in the concrete. Improperly consolidated specimens can reduce the strength. Improperly curing the specimen can also cause lower strengths. The cylinder needs to be protected from cold or hot weather since temperatures can affect both early and late strengths. Cylinders need to be transported carefully, making sure they are not jarred, bumped, or allowed to roll around. The cylinder also needs to be protected from moisture loss during transporting by wrapping it in wet burlap and plastic. Curing the specimen incorrectly will cause strength loss when tested.

IM 315 gives the proper procedure for making, curing, and testing concrete cylinders. IM 204 specifies the testing frequencies.
METHOD OF MAKING, PROTECTING, CURING & TESTING CONCRETE CYLINDERS

SCOPE
This method covers procedures for making, protecting, and curing, according to AASHTO T23. This method also covers testing concrete cylinder specimens for compressive strength, according to AASHTO T22. This test procedure is a supplement and not a replacement for the beam test to determine when a structure may be put in service.

I. MAKING, PROTECTING & CURING SPECIMENS

A. Apparatus for Making Specimens

1. 6 in. x 12 in. or 4 in. x 8 in. steel, brass, or single-use plastic vertical molds meeting the requirements of AASHTO M205.

2. Molds shall be the vertical type.

3. Tamping rods shall comply with AASHTO T23 and the following:

<table>
<thead>
<tr>
<th>Mold Size</th>
<th>Tamping Rod Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 in. x 8 in.</td>
<td>3/8 in.</td>
</tr>
<tr>
<td>6 in. x 12 in.</td>
<td>5/8 in.</td>
</tr>
</tbody>
</table>

4. Internal or external vibrators may be used. They shall comply with AASHTO T23 with the exception that the diameter of the vibrating element of the internal vibrator shall vary for each specimen size, as stated below. External vibrators shall be either a table type or a plank type.

5. Rubber hammer

6. Wood float or equivalent

B. Making Test Specimens

1. The concrete shall be sampled in accordance with IM 327, Sampling Freshly Mixed Concrete.

2. Before casting specimens, the inside surfaces of the steel or brass molds should be clean and treated with a thin coating of light grease or form oil.

3. Consolidation may be rodding with a tamping rod, or by vibration, either internal or external. Concrete with slump greater than 3 inches shall be consolidated by rodding. Concrete with slump of 1 inch to 3 inches shall be consolidated by rodding or vibration. Concrete with slump of less than 1 inch shall be consolidated by vibration.
a. **Rodding.** Specimens shall receive the proper number of roddings evenly distributed per layer as indicated in the table. The bottom layer shall be rodded throughout its depth. For each upper layer, the rod shall penetrate 1 inch into the underlying layer. After rodding each layer, the sides and ends of the mold shall be tapped with a rubber hammer until the surface of the concrete is relatively smooth. Use an open hand to tap the single-use molds. After consolidation, strike off the horizontal surface and finish with a float or trowel.

<table>
<thead>
<tr>
<th>Mold Size</th>
<th>No. of Equal Depth Layers</th>
<th>No. of Roddings per Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 in. x 8 in.</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>6 in. x 12 in.</td>
<td>3</td>
<td>25</td>
</tr>
</tbody>
</table>

b. **Internal Vibration.** Specimens shall receive the required number of insertions of a vibrator layer as indicated in the table. If more than one insertion is required, distribute the insertion uniformly in each layer. Each layer shall be vibrated only long enough to make the surface relatively smooth. The time required will vary with the consistency of the concrete. Over vibration may cause segregation. In compacting the concrete, the vibrator shall not rest on or touch the sides of the mold. When vibrating the top layer, the element shall penetrate about 1/2 inch into the bottom layer. After vibrating, tap the sides of the mold with a rubber hammer to ensure removal of entrapped air bubbles at the surface of the mold. Use an open hand to tap the single-use molds. When consolidation is complete, strike off and finish with a wood float or trowel.

<table>
<thead>
<tr>
<th>Mold Size</th>
<th>Vibrator Diameter</th>
<th>No. of Equal Depth Layers</th>
<th>No. of Insertions per Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 in. x 8 in.</td>
<td>¾ to 1 inch</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6 in. x 12 in.</td>
<td>¾ to 1 1/2 inch</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

c. **External Vibration.** Each layer shall be vibrated only until the surface is relatively smooth. Take care to ensure that the mold is rigidly attached or securely held against the vibrating table or vibrating surface. After consolidation, strike off and finish with a trowel or float.

C. **Protecting & Curing**

1. **Initial Curing.** During the first 24 hours after molding, specimens shall be stored under conditions that maintain the temperature immediately adjacent to the specimens in the range of 50°F to 80°F and prevent loss of moisture from the specimens. This may be done by covering specimens with wet burlap and placing a plastic sheet over the burlap, or use other suitable methods to ensure that the foregoing requirements are met. For concrete with minimum specified strength of 6000 psi or greater, initial curing shall be between 68°F and 78°F and maintained in a satisfactory moisture environment. A satisfactory moisture environment may be a bucket with lid filled with
lime saturated water to cover the specimens, immediately immersed after molding for up to 48 hours. Or other methods described in AASHTO T 23 may be utilized.

2. Curing to Determine Form Removal Time or When a Structure May be Put in Service. Cure test specimens as nearly as practicable in the same manner as the concrete in the structure. After 48 ± 4 hours, remove specimens from the molds. They shall be stored as near as possible to the point in the structure they represent and shall be afforded the same temperature protection and moisture environment as the structure until the time of testing. Specimens shall be tested while in the moisture condition resulting from the curing they receive.

3. Curing To Check the Adequacy of Laboratory Mix Proportions for Strength or As a Basis For Acceptance or For Quality Control. For this purpose, specimens are to be removed from the molds at the end of 16 to 24 hours and stored in a moist condition at 68°F to 81.5°F until the time of test. For concrete with minimum specified strength of 6000 psi or greater, store in a moist condition at 73.5°F ± 3.5°F until time of test. This condition can be met by immersion in saturated limewater. NOTE: Lime-saturated water is prepared by mixing 0.4 ounces of hydrated lime, with 1 gallon of water. Hydrated lime should be a minimum of 90 percent calcium hydroxide (CaOH).

4. Steam Curing. When artificial heat is used to accelerate curing, concrete specimens shall be placed with the unit being cured and shall receive the same curing as the concrete they represent. Prior to testing the specimens, the temperature of the concrete shall be lowered to the temperature of the surrounding air at a rate not to exceed 40°F per hour.

5. Special care must be given to ensure that specimens are not damaged during handling. For 16 to 24 hours after molding, specimens shall not be moved.

II. TESTING CONCRETE SPECIMENS FOR COMPRESSION

A. Apparatus

1. The testing machine shall conform to AASHTO T22. Manually operated testing machines will be accepted.

B. Time of Testing

1. Make compression tests of moist cured specimens as soon as practicable after removal from curing. Keep specimens moist by use of wet burlap or other suitable covering, which will ensure similar protection until actual time of testing.

2. The time to test specimens otherwise cured will be as directed by the engineer.

C. Test Specimens

1. Neither end of compressive test specimens when tested shall depart from the perpendicularity to the axis by more than 0.5 degrees (approximately 1/8 in. in 12 in.)
2. The ends of the specimens that are not plane within 0.002 in. shall be capped. The planeness of the ends of every tenth specimen should be checked by means of a straightedge and feeler gauge, making a minimum of three measurements on different diameters, to insure that the end surfaces do not depart from a plane by more than 0.002 in.

3. The top surface of vertically cast specimens shall be capped.

D. Capping

1. Capping equipment and procedures shall comply with that described in AASHTO T231.

2. Unbonded caps and equipment shall comply with ASTM C1231.

Unbonded caps are permitted to be used on one or both ends of a cylinder. Neoprene pads used shall meet the requirement listed in the Table 1 of C1231. Pads shall be $\frac{1}{2} + 1/16$ in. thick and diameter shall not be more than 1/16 in. smaller than inside diameter of the retaining ring. Replace pads that do not meet the dimensional requirements or exceed the maximum reuse limits specified in the Table 1 of C1231. Insert pad in the retainer before it is placed on the cylinder.

The height of the retaining ring shall be 1.0 ± 0.1 in. The inside diameter of the retaining ring shall not be less than 102 % or greater than 107 % of the diameter of the cylinder. The thickness of the retaining ring shall be at least 0.47 in. for 6 in. diameter retainers and at least 0.35 in. for 4 in. diameter retainers.

E. Test Procedure

1. Placing Specimen

   a. Place the plain (lower) bearing block with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block.

   b. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen.

   c. Carefully align the axis of the specimen with the center thrust of the spherically seated block.

   d. As the spherically seated block is brought to bear on the specimen, rotate its moveable portion gently by hand so that uniform seating is obtained.

2. Rate of Loading

   a. Apply the load continuously and without shock. Apply the load at a constant rate within the range of 20 to 50 psi per second. During the application of the first half of the estimated maximum load, a higher rate of loading may be permitted.
b. Do not make any adjustment in the controls of the testing machine while the specimen is yielding, especially in the period just before failure.

c. Increase the load until the specimen yields or fails, and record the maximum load carried by the specimen during test.

d. Note the type of failure (Figure 1) and the appearance of the concrete if the break appears to be abnormal.

F. Calculations

1. Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the cross sectional area, and express the result to the nearest 10 psi. The attached tables may be used to facilitate these computations.

![Figure 1. Compressive Fracture Types](image)

Type 1  Type 2  Type 3  Type 4  Type 5  Type 6

Figure 1. Compressive Fracture Types

![Figure 2. Compression Testing Machine](image)

Figure 2. Compression Testing Machine
April 18, 2017
Supersedes April 19, 2016

Matls. IM 315

Table for Computing lb./in.² on 6 in. x 12 in. Cylinders
Area = 28.2744 in.²

(Load in Thousands)
Load
40
41
42
43
44
45
46
47
48
49

Psi
1410
1450
1490
1520
1560
1590
1630
1660
1700
1730

Load
90
91
92
93
94
95
96
97
98
99

Psi
3180
3220
3250
3290
3320
3360
3400
3430
3470
3500

Load
140
141
142
143
144
145
146
147
148
149

Psi
4950
4990
5020
5060
5090
5130
5160
5200
5230
5270

Load
190
191
192
193
194
195
196
197
198
199

Psi
6720
6760
6790
6830
6860
6900
6930
6970
7000
7040

Load
240
241
242
243
244
245
246
247
248
249

Psi
8490
8520
8560
8590
8630
8670
8700
8740
8770
8810

50
51
52
53
54
55
56
57
58
59

1770
1800
1840
1870
1910
1950
1980
2020
2050
2090

100
101
102
103
104
105
106
107
108
109

3540
3570
3610
3640
3680
3710
3750
3780
3820
3860

150
151
152
153
154
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156
157
158
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5310
5340
5380
5410
5450
5480
5520
5550
5590
5620

200
201
202
203
204
205
206
207
208
209

7070
7110
7140
7180
7220
7250
7290
7320
7360
7390

250
251
252
253
254
255
256
257
258
259

8840
8880
8910
8950
8980
9020
9050
9090
9120
9160

60
61
62
63
64
65
66
67
68
69

2120
2160
2190
2230
2260
2300
2330
2370
2410
2440

110
111
112
113
114
115
116
117
118
119

3890
3930
3960
4000
4030
4070
4100
4140
4170
4210

160
161
162
163
164
165
166
167
168
169

5660
5690
5730
5760
5800
5840
5870
5910
5940
5980

210
211
212
213
214
215
216
217
218
219

7430
7460
7500
7530
7570
7600
7640
7670
7710
7750

260
261
262
263
264
265
266
267
268
269

9200
9230
9270
9300
9340
9370
9410
9440
9480
9510

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2480
2510
2550
2580
2620
2650
2690
2720
2760
2790

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127
128
129

4240
4280
4310
4350
4390
4420
4460
4490
4530
4560

170
171
172
173
174
175
176
177
178
179

6010
6050
6080
6120
6150
6190
6220
6260
6300
6330

220
221
222
223
224
225
226
227
228
229

7780
7820
7850
7890
7920
7960
7990
8030
8060
8100

80
81
82
83
84
85
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87
88
89

2830
2860
2900
2940
2970
3010
3040
3080
3110
3150

130
131
132
133
134
135
136
137
138
139

4600
4630
4670
4700
4740
4770
4810
4850
4880
4920

180
181
182
183
184
185
186
187
188
189

6370
6400
6440
6470
6510
6540
6580
6610
6650
6680

230
231
232
233
234
235
236
237
238
239

8130
8170
8210
8240
8280
8310
8350
8380
8420
8450

(Load in Thousands)

Table for Computing lb./in.² on 4 in. x 8 in. Cylinders

6

11-8


Area = 12.5666 in.²

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### IOWA DEPARTMENT OF TRANSPORTATION
### OFFICE OF MATERIALS
### R. KINKADE

#### CONCRETE COMPRESSION

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#### REMARKS

Signed ____________________________

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- **Unit of Material**: 4 x 8 Cylinders
- **Sampled by**: [Name]
- **Date Received**: [Date]
- **Date Reported**: [Date]
- **C-231 Tested by**: [Name]
- **C-143 Tested by**: [Name]
- **C-39 Tested by**: [Name]
Review Questions
Making & Testing Concrete Cylinders
IM 315

1. To consolidate the concrete in the cylinder if the slump is greater than 3 inches, a _____________ should be used.

2. When rodding, if the cylinder is 6 in. x 12 inches the concrete should be put into the mold in _______ equal layers. How many layers if using vibration?

3. During initial curing, how should the specimens be stored for the first 24 hours?

4. It is important that the specimen be kept _______________ until testing.
Maturity testing is performed to determine the strength of in-place concrete, using a non-destructive method by using curing temperatures. Concrete gains strength with time and temperature so by monitoring the time and temperature factors, strength can be estimated.

Maturity testing is performed and monitored by both contractors and agencies. The use of the maturity method allows contractors to open pavements earlier than when beams are used to determine pavement strength.

Developing a maturity curve and the monitoring of the time, temperature factor to calculate strength are both important pieces in the strength calculation. The calculations need to be properly performed or the strength could be incorrect. Water/cement ratio (w/c) has a big impact on strength so the curve development should be performed with concrete at the highest w/c anticipated. The beams that are made for the maturity curve should be cast according to IM 328 and tested according to IM 316 to ensure the curve is properly developed.

A maturity curve is mix specific, plant specific, project specific and material specific. If anything changes, a new curve needs to be developed. A mix could be transferred to another plant. A maturity curve developed at a plant from the same company may be transferred to another plant of the same company provided identical sources of materials are used. The transferred curve shall be validated at other plants within the company.

IM 383 explains the proper procedure to use maturity testing on a project. IM 204 specifies testing frequencies.
ESTIMATE OF PORTLAND CEMENT CONCRETE STRENGTH BY MATURITY METHOD

GENERAL
This IM outlines the procedure for using the maturity concept as a nondestructive method to estimate concrete strength.

Determination of concrete maturity (time temperature factor (TTF)) and estimating in place concrete strength is a two-step procedure as follows:

1. Maturity Curve - A relationship must be established between the maturity (TTF) and the concrete strength as measured by destructive methods (that is, through testing of beams or cylinders). The development of the maturity-strength curve shall be done at the plant site at the beginning of construction using project materials and the project proportioning and mixing equipment.

2. Field Maturity - The second step is the temperature monitoring of the placed concrete. Temperature probes are installed in the concrete and the temperature is measured. From those measurements, along with the age at which the measurements were taken, the maturity (TTF) is calculated and used to estimate the concrete strength. A maturity meter may also be used to determine the maturity value (TTF).

For concrete furnished from a construction or stationary mixer, which is in place prior to construction of the specified project, a maturity curve may be established ahead of actual construction of the specified project. The test specimens shall be cast with concrete made from the same plant and using the same materials source as will be used in the specified project. The agency shall be informed and have an opportunity to observe the development of the maturity curve and validation.

THE MATURITY CONCEPT
The hydration of cement and gain in strength of the concrete is dependent on both curing time and temperature. Thus, the strength of the concrete may be expressed as some function of time and temperature. This information can then be used to determine the strength of concrete without conducting physical tests. The time-temperature function commonly used is the maturity concept proposed by Nurse-Saul (ASTM C1074),

\[ M (\degree C \times \text{hours}) = \sum [(T - T_0) \Delta t] \]

Where \( M \) is the maturity in \( \degree C \)-hours [M is also termed the time-temperature factor (TTF)], \( \Delta t \) is the time interval in hours (or days), \( T \) is the average concrete temperature during the time interval \( \Delta t \), and \( T_0 \) is the datum temperature at which concrete ceases to gain strength with time. The value of \( T_0 = (-10\degree C) \) is most commonly used. As a result, Equation 1 becomes:

\[ M (\degree C \times \text{hours}) = \sum [(T + 10) \Delta t] \quad \text{Equation 2} \]

EQUIPMENT
- 12 - 6 in. x 6 in. x 20 in. beam molds
- 1 each shovel (square point), rubber hammer or equivalent, and wood float or equivalent
- Hydraulic testing machine – center point loading flexural
• Maturity meter – a device that automatically measures, records, and displays the maturity (TTF) value
• Hand-held thermometer - a temperature measuring device with a thermocouple wire or probes readable to the nearest 0.1°C and accurate to 1°C.
• Temperature data logger – a device that measures temperature and electronically stores the readings a minimum of once per hour

ESTABLISHMENT OF MATURITY-STRENGTH RELATIONSHIP - MATURITY CURVE
To establish a maturity-strength relationship for a concrete mix, a maturity meter and a hydraulic testing machine are needed. The following procedure shall be used: (NOTE: Before using any maturity meter, check to be sure the datum temperature is set to -10°C.)

1. Cast a minimum of twelve beams, as per IM 328. Test the entrained air content of the concrete being used to cast the beams, as per IM 327. Record these values. The concrete shall meet specifications, with a minimum air content of 5.5%. There is a direct relationship between w/c ratio and strength. The concrete used to develop the maturity-strength relationship shall be at the maximum w/c ratio expected during production, or within 0.02 of the maximum w/c ratio of the mix design. The beams shall be cast from a batch of at least 3 cu. yd.

2. When using thermocouple wire, strip ½” to ¾” of the coating from each end of the two wires and twist ends. Embed a thermocouple wire near each end of a test beam (when flexural strength is to be determined) to monitor the temperature. This beam will be the last to be tested. A probe shall be inserted near each beam end to the approximate mid-depth and such that they are approximately 3 in. from each side and each end. Loop the wire around the beam box handles to prevent the wire from being inadvertently pulled out of the beam. The average of the two readings will be used in the development of the maturity curve. A maturity meter shall be used to develop the curve. A temperature data logger may be used to develop the curve and the maturity (TTF) shall be calculated from hourly readings.

3. Cast, cure, and test the beams at the plant site. Test strength in accordance to IM 316. This will allow a maturity meter to be protected from the weather and theft. The meter can be stored in a lab trailer or vehicle with the probes run outside to the beam in the sandpit. The beams shall be covered with plastic immediately after casting and prior to form removal. If possible, wet burlap should be placed over the surface of the beams under the plastic. The forms shall be removed the following day. All beams shall be cured, buried in a pit of wet sand after form removal, until they are tested. Beams may be cured in a saturated lime tank, only if the water temperature is controlled at 60 to 80 °F.

   Precaution: When the concrete temperature is below 50°F, maturity strength development will cause over extended maturity (TTF) values. Development of strength maturity relationship should be performed on concrete with temperatures above 50°F.

   When air temperatures are expected to fall below 40°F, place the beams on a piece of foam board or plywood to prevent the cold ground from lowering beam temperatures. Placing insulation over the beams to retain heat may also be warranted.

4. Determine maturity (TTF) and strength values at four different ages. Test three specimens for strength at each age and calculate the average strength at each age. The maturity (TTF) value shall be calculated from a temperature reading at the time the specimen is tested for strength.
The tests shall be spaced such that they are performed at somewhat consistent intervals of time and span a range in strength that includes the opening strength desired. Ideally, there would be at least two sets of strength values below the opening strength. For Class C or QMC mixtures, the first set of beams will typically be tested at an age of approximately 8 to 12 hours, depending on concrete temperature. Test age may need to be increased when concrete temperature is below 50 °F, when retarders are used, or when high replacement mixes are used. Test age may need to be decreased at higher temperatures above approximately 80°F. The average strength of the first set of beams must be less than 425 psi for the curve to be valid.

If the maturity curve is intended for use in determining the time to begin joint sawing, additional test specimens will need to be cast and strength testing must begin at lower maturity values.

For pavements, a minimum flexural strength of 500 psi is required for opening. (See Article 2301.03). For structural concrete, a minimum flexural strength of 575 psi is required before forms may be removed and concrete may be subjected to flexural loading. Strength requirements vary for determining when forms for roofs of culverts may be removed (See Article 2403.03). Testing intervals may need to be increased over those for paving.

For structural concrete where compressive strength of 4500 psi or greater is required, develop a maturity curve utilizing cylinders for compressive strength. Ensure the last set of cylinders is greater than the required design strength. Cast and cure, in accordance with IM 315, a minimum of 15 cylinders and place probes in two of the cylinders. Test a set of three cylinders at each age of 1, 3, 7, 14, and 28 days (or earlier if already above design strength). This maturity curve may be utilized for other units with lower compressive strength requirements. The DME may also approve this curve for items with flexural strength requirements.

5. Plot the measured strength against the corresponding values of maturity at different ages, as determined by the maturity meter or by hand methods. Use the spreadsheet provided by the District Materials Concrete Technician to determine maturity-strength relationship. The maturity (TTF) value corresponding to the required opening strength shall be used to determine when the pavement or structure may be loaded. An example of the Maturity-Strength Development form, generated by the computer program, is included at the end of this IM. This form shall be reviewed by the DME. Copies will be provided to the Project Engineer, DME, Concrete Materials Engineer, and the contractor.

FIELD MATURITY (TTF) PROCEDURE – ESTIMATE IN PLACE CONCRETE STRENGTH

Placement of the Temperature Probes
Strip ½” to ¾” of the coating from each end of the two wires and twist the ends together before inserting them into the fresh concrete.

Pavements

For pavements, insert the temperature probe into the concrete until the end is at approximately the pavement mid-depth and 1.5 feet from the edge of the pavement. The wire ends are the points at which the temperature measurement is taken. Insertion may be accomplished by attaching the wire ends to a wooden dowel and embedding it into the slab. Check to ensure the concrete is consolidated around the dowel. The portion of the dowel that protrudes above the pavement should be cut or broken off after the testing is completed.
Probes may be placed at any point along the pavement slab. A minimum of two probes shall be placed in each day’s placement with one at the end of the days run. On days when there is a large difference between daytime high temperatures and nighttime low temperatures, placing additional probes near the beginning of the day’s run and at a point near the midday location provides useful information. The concrete placed during the middle of the day can gain strength faster than the concrete placed at the beginning of the day because of daytime heating. Place probes at side roads, or other locations, where opening to traffic is critical.

Structures

For structures, a minimum of two probes shall be attached to the reinforcing steel near the edge at the upper corner of the exposed surface. (See Figure 1 at the end of this IM.) The probe should be wrapped around the rebar and taped with approximately 1 to 2 inches extending below the rebar to prevent the probe from damage and removal during concrete placement. The rebar should also be taped 2 to 3 inches on both sides of the probe location to prevent contact with the reinforcing steel. (See Figure 2 at the end of this IM.)

**Temperature Data Collection and Maturity (TTF) Calculation**

**Handheld thermometers (Pavements)**

Typically, a handheld thermometer is used to collect temperature readings for pavements. The probe wire ends, extending out from the concrete, may be connected to a plug. A plug with thermocouple wires and clips attached to the handheld thermometer may also be used to connect to the wires extending from the concrete. Be careful to connect the copper wire to the copper plug prong (+).

Once the wires are placed, an initial temperature of the concrete shall be taken and recorded. Temperature readings should be taken in the morning and late afternoon as a minimum for standard A, B and C mixtures. For the fast-setting mixtures, readings should be taken every few hours, depending on weather conditions and mixture.

A Maturity Data Recording Sheet, provided at the end of this IM, may be used to record the temperature readings and calculate the maturity values.

A continuous temperature data logger is required for monitoring structures. The maturity value shall be calculated based on hourly readings obtained from the device. The device may also be used for monitoring pavements.

If a maturity meter is being used to monitor either pavements or structures, it should be connected to the probe as soon as possible to begin data collection. The maturity (TTF) value may be read directly from the maturity meter. Some maturity meters are not moisture proof and will be permanently damaged if not protected from water or moisture.

It is the responsibility of a Level I PCC technician to place probes, perform all calculations, and submit forms to the Engineer. The Level I PCC technician may supervise other personnel to place probes, obtain temperature readings or read maturity values.

**Implementation**

For pavements, it is the intent of the procedure to use the maturity method to open the pavement
to traffic from the first day of paving, including the days of development of new curves.

During maturity curve development, a preliminary maturity TTF value may be used to determine opening strength of pavement placed during the first day of paving.

The preliminary TTF will be the TTF value, at a particular age when the average strength of the three beams used for development of the strength-maturity curve meets or exceeds the required opening strength.

After curve has been established and approved by the DME, only the approved maturity TTF value shall be used to open pavement sections.

In all cases, the Engineer will determine if adequate strength has been achieved and the time when a pavement may be opened to traffic based on TTF measurements collected from that pavement.

When multiple plants are being used in accordance with Article 2301.02.C,4,a, use the most conservative curve (highest opening TTF) to determine when the pavement may be opened. Use the most conservative curve if multiple cement changes have occurred.

A maturity curve developed at a plant from the same company may be transferred to another plant of the same company provided identical sources of materials are used. The transferred curve shall be validated at other plants within the company.

For structures, since maturity is to be used on units exposed to flexural loading, the maturity curve should be developed early in the project during placement of concrete exposed to compressive stress. If this is not possible, concrete placed on the same day as development of the strength-maturity curve may be loaded at a particular age using either of the first day placement criteria required for pavements.

**Curve Validation**

A curve validation is required once every 90 calendar days during normal plant production. If the plant has not supplied concrete to the project for a period of greater than 90 days, the curve may begin on the first day of startup. The validation tests shall be conducted to determine if concrete strength is being represented by the current maturity curve. Cast and cure three (3) beams using the same procedure and manner as used to develop the current maturity curve. Test all three beams as close as possible to the maturity value determined to represent the opening strength of the pavement or the flexural loading strength or form removal strength of the structure. Normal production concrete may be used for curve validation.

**Pavements**

For pavements, if the average calculated strength value at the TTF the validation beams were tested is within the range of ±50 psi of the original curve, the original curve shall be considered validated.

**Structures – compressive strength up to 4000 psi**

For structures, if the average calculated strength is greater than the original curve at the TTF the validation beams were tested, the original curve shall be considered validated.
Structures – compressive strength 4500 psi or greater

A curve validation is required once every month during placement of concrete with compressive strength requirement of 4500 psi or greater. If the average calculated compressive strength is greater than the original curve represented by the cylinders tested, the original curve shall be considered validated.

An example of the Validation of the Maturity Curve is included at the end of this IM. Copies shall be provided to the RCE, DME, and the contractor.

This validation procedure is a check to ensure the mix is basically the same as originally tested. If the test results indicate a new curve must be developed, this should be done in a timely manner. The curve currently being used shall be continued until new beams can be cast and at that point the implementation procedure described above shall be followed.

Factors Requiring a New Curve
Changes in material sources, proportions, and mixing equipment all affect the maturity value of a given concrete mixture. Development of a new maturity curve due to material source or proportion changes in a concrete mix may be waived by use of the validation procedure.

The following will require a new curve to be developed:

- The validation beams tested meet either of the following conditions:
  - For pavements, the average calculated strength at the TTF tested is below the minimum range (-50 psi) of the original maturity curve.
  - For structures, the average calculated strength at the TTF tested is lower than the original maturity curve.

- The w/c ratio of the production concrete exceeds the w/c ratio of the concrete used to develop the strength-maturity curve by more than 0.02.

Maturity Meter Calibration
The four channel Type T thermocouple (Humboldt or Gilson type) maturity meters shall be calibrated yearly to ensure proper temperature sensing. The calibration may be performed at the Central Laboratory, before the start of each construction season. To ensure accurate temperature measurement, all other maturity meters and handheld thermometers should also be checked at least yearly against a certified thermometer or other calibrated meter at the District or Central Laboratory. Some maturity meters may need to be sent to the manufacturer for calibration.
### Iowa Department of Transportation

**Maturity - Field Data**

- **Project:** FMX-CO74(68)--55-74
- **Date Placed:** 4/26/2009
- **Maturity Curve #:** CV-2
- **County:** Palo Alto
- **Mix:** C-3WR-C20
- **Contractor:** Cedar Valley
- **Certified Tech:** John Smith ANE999

#### SITE 1

<table>
<thead>
<tr>
<th>Date and Time (AM or PM)</th>
<th>Age (hours)</th>
<th>Temp (deg C)</th>
<th>TTF at age (deg C-hr)</th>
<th>Sum TTF (deg C-hr)</th>
<th>Air Temp (deg C)</th>
</tr>
</thead>
<tbody>
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<td>0</td>
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\]

**TTF:** 1468

Value in box should be greater than or equal to required TTF.

#### SITE 2

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<tbody>
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**Total Time (hrs):** 0.0

\[
TTF = \left(\frac{\text{Temp} + \text{Temp}_{\text{prev}}}{2} + 10\right) (\text{Age} - \text{Age}_{\text{prev}})
\]

**TTF:**

Value in box should be greater than or equal to required TTF.

**cc:** RCE
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<th>LOAD AT BREAK (lbs)</th>
<th>BREAK VALUE (lbs)</th>
<th>LOCATION</th>
<th>WIDTH (in)</th>
<th>DEPTH (in)</th>
<th>FLEXURAL COEFFICIENT</th>
<th>FLEXURAL STRENGTH CPL (psi)</th>
<th>AGE AT BREAK (hours)</th>
<th>TTF CH 1 (psi)</th>
<th>TTF CH 2 (psi)</th>
<th>AVERAGE TTF (psi)</th>
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<td>1399</td>
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**MIX INFORMATION**

- **AIR:** 7.5%
- **SLUMP:** 3 in.
- **w/c:** 0.452
- **MIX:** C-4WR-C20
- **FLY ASH SOURCE:** FA013C
- **GGBFS SOURCE:**
- **CEMENT SOURCE:** PC0802
- **COARSE AGGREGATE SOURCE:** A63002
- **FINE AGGREGATE SOURCE:** A25518
- **WATER REDUCER BRAND:** KB-1000
- **Add. Rate:** 18oz/yd
- **AIR ADMIXTURE BRAND:** Polychem SA
- **Add. Rate:** 4.0 oz/yd
- **METHOD OF DEVELOPMENT:** Maturity Meter

**Desired Flexural Strength (MOR-CPL):** 500 psi

**REQUIRED TTF:** 1060 hours

**Maturity Curve of All Flexural Strengths**

**Comments:**
- Contractor Certified Technician - Jon Smith
- Monitor - Jane Doe
- **Cert. #:** SE9999
- **Date:** May 11, 2014
- Monitor witnessed.
- Break first set @ 6:00 am, May 12th. Monitor witnessed.
- Break second set @ 8:30 am, May 12th. Monitor unable to witness.
- Break third set @ 7:30 am, May 13th. Monitor unable to witness.
- Break fourth set @ 10:00 am, May 13th. Monitor witnessed.
- Maturity Curve Reviewed - Sam Smith
- **District Materials Engineer**

---

**Diagram:**

- Maturity Curve
- Flexural Strength (psi) vs. Log of TTF (C-hours)
- Regression: Strengths

---

October 15, 2019
Supersedes April 16, 2019
Matls. IM 383
**VALIDATION OF MATURITY CURVE**

**VAL. PROJ. #:** NHSX-092-5(51)--3H-91  
**CURVE #:** IC051109  
**MONITOR:** Jane Doe  
**CONTRACTOR:** Concrete Contractor  
**INSPECTOR:** Jon Smith  
**Validation DATE:** 9/25/15

<table>
<thead>
<tr>
<th>BEAM #</th>
<th>LOAD AT BREAK (lbs)</th>
<th>BREAK VALUE (lbs)</th>
<th>WIDTH (in)</th>
<th>DEPTH (in)</th>
<th>FLEXURAL COEFFICIENT</th>
<th>FLEXURAL STRENGTH (psi)</th>
<th>AGE AT TTF (hours)</th>
<th>TTF (CH 1)</th>
<th>TTF (CH 2)</th>
<th>AVERAGE TTF</th>
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<td>44.5</td>
<td>1516</td>
<td>1545</td>
<td>1531</td>
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</table>

**AIR:** 8

**SLUMP:** 3.75

**w/c:** 0.465

**FLY ASH:** FA013C

**CEMENT:** PC0802

**COARSE AGGREGATE:** A63002

**INTERM. AGGREGATE:** 0

**FINE AGGREGATE:** A25518

**WATER REDUCER:** KB-1000

**Add. Rate:** 18oz/yd

**Add. Rate:** 4.0 oz/yd

**Method of Development:** Maturity Meter

**REQUIRED TTF:** 1060

**TTF @ Break** 1531

**Beam 1** MOR (psi) 508

**Beam 2** MOR (psi) 562

**Beam 3** MOR (psi) 539

**Beam Avg.** MOR (psi) 536

**Calculated psi @ TTF**

<table>
<thead>
<tr>
<th>Range</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>516</td>
</tr>
<tr>
<td>Maximum</td>
<td>616</td>
</tr>
</tbody>
</table>

**Comments:**

Monitor unable to make casting on 9-23-15

Monitor witness break on 9-25-15

Validation strength above the upper limit does not require a new curve.

**Contractor Certified Technician:** Jon Smith

**Maturity Curve Validation Reviewed:** Sam Smith

**cc:** RCE, Contractor

**Maturity.xls**

**Sep-15**
Figure 1. Typical thermocouple location placement in pier cap
Use similar method for thermocouple placement in other structural elements.

Figure 2. Typical attachment of thermocouple to reinforcing steel
**Maturity - Field Data**

**Form M142**

**Project:** __________________________  
**Date Placed:** __________  
**Maturity Curve #:** __________

**County:** __________________________  
**Mix:** __________

**TTF Required for Opening or Loading:** __________

### SITE 1

| Section of Pavement for Opening or Structural Unit for Loading by Maturity |
| Probe # |

| Structural Unit or Probe Location From: | Probe Location To: |

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Age (hours)</th>
<th>Temp (deg C)</th>
<th>TTF (deg C-hr)</th>
<th>Sum TTF (deg C-hr)</th>
<th>Air Temp (deg C)</th>
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</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ TTF = \left( \frac{\text{Temp} + \text{Temp}_1}{2} + 10 \right) (\text{Age}_1 - \text{Age}_1) \]

**TTF:** __________  
Value in box should be greater than or equal to required TTF.

### SITE 2

| Section of Pavement for Opening or Structural Unit for Loading by Maturity |
| Probe # |

| Structural Unit or Probe Location - From: | To Probe Location: |

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Age (hours)</th>
<th>Temp (deg C)</th>
<th>TTF (deg C-hr)</th>
<th>Sum TTF (deg C-hr)</th>
<th>Air Temp (deg C)</th>
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<tbody>
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<td>Enter</td>
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<td>0</td>
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</table>

\[ TTF = \left( \frac{\text{Temp} + \text{Temp}_1}{2} + 10 \right) (\text{Age}_1 - \text{Age}_1) \]

**TTF:** __________  
Value in box should be greater than or equal to required TTF.

---

**cc:** RCE, Central Materials, Contractor  
**Contractor Representative**  
**Agency Representative**

---

**12-13**
Review Questions
Strength of Portland Cement Concrete
Using the Maturity Method
IM 383

1. What are the two steps in using the maturity process?
   1. ________________________________
   2. ________________________________

2. What are the two factors that the strength of concrete is dependent upon?

3. How many beams are cast to develop a maturity curve?

4. What is the minimum size batch of concrete used to cast beams for maturity?

5. When developing a curve, maturity values are determined at how many different ages?

6. Where are the probes placed in the fresh concrete after it is placed on the grade?

7. What is the minimum amount of probes that shall be placed in each day’s placement?

8. How often are validation tests conducted?

9. How many beams are cast for validation tests?
Maturity TTF Example Problem

Using the formula below, calculate the maturity value (TTF) for each time interval and the TTF sum value.

\[ TTF_i = \left( \frac{Temp_{(i)} + Temp_{(i-1)}}{2} + 10^\circ \right) \times (Age) \]

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Age (hrs)</th>
<th>Temp (deg C)</th>
<th>TTF at age</th>
<th>Sum TTF</th>
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</thead>
<tbody>
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<td>34.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10/10/17</td>
<td>8:00 PM</td>
<td></td>
<td>34.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/11/17</td>
<td>7:00 AM</td>
<td></td>
<td>42.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Solve:

\[ TTF_{8:00 PM} = \left( \frac{Temp_{(8:00 PM)} + Temp_{(8:00 AM)}}{2} + 10^\circ \right) \times (Age) \]

\[ = \left( \frac{34.6^\circ + 34.6^\circ}{2} \right) + 10^\circ \times (12 \text{ hrs}) \]

\[ = (44.6^\circ) \times (12 \text{ hrs}) \]

\[ = 535 \text{ deg C-hr} \]

\[ TTF_{7:00 AM} = \left( \frac{Temp_{(7:00 AM)} + Temp_{(8:00 PM)}}{2} + 10^\circ \right) \times (Age) \]

\[ = \left( \frac{42.9^\circ + 34.6^\circ}{2} \right) + 10^\circ \times (11 \text{ hrs}) \]

\[ = (48.75^\circ) \times (11 \text{ hrs}) \]

\[ = 536 \text{ deg C-hr} \]
Maturity TTF Problem #1

Using the formula below, calculate the maturity value (TTF) for each time interval and the TTF sum value.

\[ TTF_i = \left( \frac{Temp(i) + Temp(i-1)}{2} + 10^\circ \right) \times (Age) \]

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Age(hrs)</th>
<th>Temp (deg C)</th>
<th>TTF at age</th>
<th>Sum TTF</th>
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<tr>
<td>8/12/17</td>
<td>1:00PM</td>
<td>4</td>
<td>29°</td>
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</table>

TTF: 

Solve:

\[ TTF_{1:00PM} = \left( \frac{Temp(1:00PM) + Temp(9:00AM)}{2} + 10^\circ \right) \times (Age) \]
Maturity TTF Problem #2

Using the formula below, calculate the maturity value (TTF) for each time interval and the TTF sum value.

\[ TTF_i = \left( \frac{Temp_{(i)} + Temp_{(i-1)}}{2} + 10^\circ \right) \times (Age) \]

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Age (hrs)</th>
<th>Temp (deg C)</th>
<th>TTF at age</th>
<th>Sum TTF</th>
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<td>0</td>
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<td>17.9°</td>
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<td>22.9°</td>
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TTF: __________

Solve:

\[ TTF_{(8:00 p.m.)} = \left( \frac{Temp_{(8:00 PM)} + Temp_{(6:00 AM)}}{2} + 10^\circ \right) \times (Age) \]

= 

\[ TTF_{7:00 AM} = \left( \frac{Temp_{(7:00 AM)} + Temp_{(8:00 PM)}}{2} + 10^\circ \right) \times (Age) \]

= 

Maturity TTF Problem #3

Using the formula below, calculate the maturity value (TTF) for each time interval and the TTF sum value.

\[ TTF_i = \left( \frac{Temp(i)+Temp(i-1)}{2} + 10^\circ \right) \ast (Age) \]

<table>
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<tr>
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<th>Time</th>
<th>Age (hrs)</th>
<th>Temp (deg C)</th>
<th>TTF at age</th>
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<td>22.2°</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10/2/17</td>
<td>9:30 AM</td>
<td></td>
<td>19.0°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/2/17</td>
<td>4:30 PM</td>
<td></td>
<td>26.5°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/3/17</td>
<td>8:30 AM</td>
<td></td>
<td>15.9°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TTF: ____________

Solve:

\[ TTF_{(9:30 AM)} = \left( \frac{Temp(9:30 AM)+Temp(5:00 PM)}{2} + 10^\circ \right) \ast (Age) \]

= 

\[ TTF_{4:30 PM} = \left( \frac{Temp(4:30 PM)+Temp(9:30 AM)}{2} + 10^\circ \right) \ast (Age) \]

= 

\[ TTF_{8:30 AM} = \left( \frac{Temp(8:30 AM)+Temp(4:30 PM)}{2} + 10^\circ \right) \ast (Age) \]

= 

12-23
Maturity TTF Problem #4

Solve the following maturity problem, using the Field Maturity Testing program found at the Iowa DOT Office of Construction and Materials web page -

https://iowadot.gov/construction_materials/portland-cement-concrete-pcc

<table>
<thead>
<tr>
<th>Project:</th>
<th>Date Placed:</th>
<th>Maturity Curve #:</th>
</tr>
</thead>
<tbody>
<tr>
<td>County:</td>
<td>Mix:</td>
<td>Certified Tech:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SITE 1</th>
<th>Section of Pavement for Opening or Structural Unit for Loading by Maturity</th>
<th>Probe #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Unit or Probe Location From:</td>
<td></td>
<td>Probe Location To:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date (Enter)</th>
<th>Time (Enter)</th>
<th>Age (hours) Enter</th>
<th>Temp (deg C) Enter</th>
<th>TTF at age (deg C-hr) Enter</th>
<th>Sum TTF (deg C-hr) Enter</th>
<th>Air Temp (deg C) Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>08/08/03</td>
<td>10:00 AM</td>
<td>0.00</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>08/08/03</td>
<td>05:00 PM</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/09/03</td>
<td>09:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/09/03</td>
<td>04:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/10/03</td>
<td>08:00 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/10/03</td>
<td>02:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$$TTF = \left( \frac{Temp + Temp_m}{2} + 10 \right) (Ag_{\alpha} - Ag_{\alpha_1})$$

TIF: Value in box should be greater than or equal to required TTF.
Maturity TTF Problem #5

Solve the following maturity problem, using the Field Maturity Testing program found at the Iowa DOT Office of Construction and Materials web page -

https://iowadot.gov/construction_materials/portland-cement-concrete-pcc

<table>
<thead>
<tr>
<th>Maturity - Field Data</th>
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</thead>
<tbody>
<tr>
<td>Project:</td>
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<tr>
<td>Date Placed:</td>
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<tr>
<td>County:</td>
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<tr>
<td>Mix:</td>
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<tr>
<td>Contractor:</td>
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<td>Certified Tech:</td>
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</table>

<table>
<thead>
<tr>
<th>TTF Required for Opening or Loading:</th>
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<table>
<thead>
<tr>
<th>SITE 1</th>
<th>Section of Pavement for Opening or Structural Unit for Loading by Maturity</th>
<th>Probe #</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Structural Unit or Probe Location From:</td>
<td>Probe Location To:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date Enter</th>
<th>Time Enter</th>
<th>Age (hours) Enter</th>
<th>Temp (deg C) Enter</th>
<th>TTF at age (deg C-hr) Enter</th>
<th>Sum TTF (deg C-hr) Enter</th>
<th>Air Temp (deg C) Enter</th>
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</thead>
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<td>08:00 AM</td>
<td>0.00</td>
<td>18.1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>07/02/03</td>
<td>09:00 AM</td>
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<td>17.3</td>
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<tr>
<td>07/03/03</td>
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<td>07/03/03</td>
<td>10:00 AM</td>
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<td>19.6</td>
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<td></td>
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<tr>
<td>07/03/03</td>
<td>04:00 PM</td>
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<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07/05/03</td>
<td>07:00 AM</td>
<td></td>
<td>17.8</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

\[
\text{TTF} = \left(\frac{\text{Temp} + \text{Temp}_{\text{H1}} + 10}{2}\right)(\text{Age}_1 - \text{Age}_0) \quad \text{TTF:}\]

Value in box should be greater than or equal to required TTF.
Measuring Length of Drilled Concrete Cores

Core lengths are measured to determine the thickness of Portland cement concrete pavements.

An incentive is given to the Contractor based on thickness of the cores over design thickness. When cores greater than one inch deficient in length are found, more cores will be taken to determine the area of removal.

Core locations are determined by the District Materials Engineer to ensure random locations are used. Cores are drilled by the contractor and witnessed by the agency. Cores shall be measured on the grade by the agency or taken into immediate possession. In order to avoid problems with core diameter, check that the core diameter is 4 inches when the first cores are drilled. A 4.25” outside diameter (OD) bit will produce 4” cores.

Core ends must be free of conditions not typical of the surfaces of the structure. Remove pieces of aggregate subbase stuck on the core. A large screwdriver, hammer, and wire brush may be used to force subbase material from the bottom of the core. Use enough force to remove the material, but not cause damage to the core. If aggregates are firmly cemented, or encased with mortar, it may not be possible to remove them without damage to the core.

The length of the cores is determined in accordance with Material IM 347. Before any measurements of the core length are made, calibrate the apparatus with suitable gauges so errors caused by mechanical imperfections are known.

Cores should be measured in English units. Read each of the nine measurements directly to 0.10 in. (2.5 mm), and interpolate to the nearest 0.05 in. (1 mm) by estimation. The spreadsheet available from the Office of Materials will convert to Metric units when required. The spreadsheet can be used to determine the thickness incentive in accordance with Materials IM 346.
The core on the left is an example of a core that has been properly cleaned before measuring. The core on the right is an example of a core that has excessive material that needs to be removed prior to measurement.
MEASURING LENGTH
OF DRILLED CONCRETE CORES

SCOPE

This method covers the procedure for determining the length of a core drilled from a PC Concrete structure, particularly from a PC Concrete pavement. The procedure is a modification of AASHTO T 148.

PROCEDURE

A. Apparatus

1. The apparatus consists of a calipering device that will measure the length of axial elements of the core.

2. The apparatus is designed so the specimen is held with its axis in a horizontal position by guide rods when making circumferential measurements, and a stand placed upon the guide rods for making a center measurement. The device is equipped with an auxiliary wheel that rests on the specimen and is calibrated such that one-half of a revolution of the wheel represents one-eighth the circumference of a 4 in. (100 mm) diameter core.

3. The device is constructed so the specimen is brought into contact with a single flat-faced probe 3/8 in. (10 mm) in diameter mounted on a fixed end of the device.

4. The measuring rod, which makes contact with the end surface of the specimen, is rounded to a radius of 1/8 in. (3 mm) and is mounted on a moveable plate, which in turn is mounted on guide rods. One guide rod is provided with a scale on which the length readings are made. The graduations of the scale are spaced at 0.10 in. (2.5 mm) intervals.

5. The apparatus provides for the accommodation of specimens of different nominal lengths over a range of 4 to 11 in. (100 mm to 275 mm).

6. The calipering apparatus is designed so it is possible to make a length measurement at the center of the specimen and at eight additional points spaced equally along the circumference of a circle whose center point coincides with the end area of the specimen and whose radius is not less than one-half, nor more than three-fourths, of the radius of the specimen.

7. The apparatus is stable and sufficiently rigid to maintain its shape and alignment without a distortion or deflection of more than 0.01 in. (0.25 mm) during all normal measuring operations.
B. Test Specimens

1. Cores used as specimens for length measurement must be in every way representative of the concrete in the structure from which they are removed. The specimen is to be drilled with the axis normal to the surface of the structure, and the ends must be free from all conditions not typical of the surfaces of the structure. A large screwdriver, hammer and wire brush may be used to force subbase material from the bottom of the core. Use enough force to remove the material, but not cause damage to the core. If the material is firmly cemented, or encased in mortar, it may not be possible to remove. (Figures 2 and 3) Cores that show abnormal defects or that have been damaged appreciably in the drilling operation should not be used.

C. Test Procedure

1. Before any measurements of the core length are made, calibrate the apparatus with suitable gauges so errors caused by mechanical imperfections are known. When these errors exceed 0.01 in. (0.25 mm), suitable corrections must be applied to the core length measurements.

2. Place the stand on the guide rods and place the specimen on the stand for the center point measurement. The smooth end of the core, that is, the end that represents the upper surface of a pavement slab or a formed surface in the case of other structures is to be positioned facing the fixed end of the measuring device. Bring the specimen into contact with the stud in the fixed end, slide the movable plate until it is in contact with the specimen and record the length.

3. Remove the stand, place the specimen directly on the guide rods and make another measurement as described in C2.

4. Place the small auxiliary wheel on the specimen so the scribed marks on the wheel are in alignment. Rotate the specimen until the marks are again in alignment (1/2 revolution of the wheel) and make another measurement. Continue in this manner until eight measurements in addition to the center measurements have been made. If the core is not 4 inches in diameter (typically 3.75 or 4.25 inches), the DME may allow alternative methods to be used.

5. Read each of the nine measurements directly to 0.10 in. (2.5 mm), and interpolate to the nearest 0.05 in. (1 mm) by estimation.

6. If, in the course of the measuring operation, it is discovered that at one or more of the eight circumferential measuring points the surface of the specimen is not representative of the general plane of the core end because of a small projection or depression, rotate the specimen slightly about its axis, and make another set of measurements with the specimen in the new position. If the center measurement is not representative of the general plane of the core end, it should not be used in computing the length of the core.

7. If some damage from drilling is apparent, no measurements are to be made in the damaged area. Reposition the core to avoid the areas when measuring the length. If these areas cannot be avoided, the length measurements made in these areas are not
to be used in computing the length of the core. In no case, are fewer than seven measurements to be used in determining the core length.

D. Report

1. The individual observations are to be recorded to the nearest 0.05 in. (1 mm) and the average of the nine measurements expressed to the nearest 0.05 in. (1 mm) and shall be reported as the length of the concrete core.

E. Precautions

1. Be careful to move the core away from the stud in the fixed end slightly when turned, so the stud will retain its proper length and shape.

Figure 1. Concrete Core in Measuring Apparatus
Figure 2. Concrete core with granular subbase attached.

Figure 3. Concrete core with granular subbase removed.
Review Questions
Measuring Length
Of Drilled Concrete Cores
IM 347

1. The testing apparatus will measure cores ________ inches in diameter and between ______ and ______ inches in length.

2. The ends of the core must be free from all conditions not typical of the surfaces of the structure, such as subbase materials.
   
   True ___________
   
   False ___________

3. Measurements are taken in the __________ and at ________ additional points along the circumference.

4. If a core is damaged but you are able to get five good readings, the core measurements can be used.
   
   True _________
   
   False _________
FLOWABLE MORTAR

The time of efflux of flowable mortar is determined to ensure adequate filling ability. There are critical and non-critical flow times that need to be determined by testing the mix.

Flowable mortar designs are performed by the Iowa DOT. Testing for flow times is done at the project by the contractor or DOT.

The design of the flowable mortar mix is important to ensure the mixture has adequate filling ability and can meet the flow times required. Inadequate mix design and flowing ability of a flowable mortar may cause voids under pavements and structures, which could eventually cause failures. When air is added to flowable mortar the flow is increased. There is a critical flow time for the inside of culverts, between beams, and under bridges, which is 10-16 seconds. The non-critical flow time for open trenches or below beams is 10-26 seconds.
DETERMINING FLOW OF GROUT MIXTURES  
(FLOW CONE METHODS)

SCOPE

This method of test covers the procedure to be used both in the laboratory and in the field for determining the flow of grout mixtures by measuring the time of efflux of a specified volume of grout from a standardized flow cone.

The procedure is a modification of ASTM C939 and D6449.

APPARATUS

1. Flow cone as specified in ASTM C939 with a 1/2 inch orifice for flowable mortar (See Figure 1).


3. Stopwatch accurate and readable to 0.2 seconds

4. Level

5. Calibration jug or container to hold a quantity of water equal to 1725 mL

CALIBRATION OF CONE

1. The flow cone shall be firmly mounted in such a manner that the top will be level and the cone free from vibration (use level, rigid, horizontal surface).

2. Level the cone by adjusting the mounting forks.

3. Close the discharge tube of the cone by placing a finger over the lower end. (Be sure not to disturb the leveled cone.)

4. Introduce 1,725 ± 1 mL of water into the cone.

5. Adjust the pointer so that the point just comes into contact with the water.

6. Start the stopwatch and remove the finger simultaneously. Stop the stopwatch when the flow stops. The elapsed time should be 8.0 ± 0.5 seconds for the ½ inch orifice and 4.0 ± 0.5 seconds for the 3/4 inch orifice.
SAMPLE

The test sample shall consist of 1,725 ± 1 mL of grout.

PROCEDURE


2. Moisten the inside surface of the flow cone.

3. Place a finger over the discharge opening.

4. Introduce grout into the cone until the grout surface rises into contact with the pointer.

5. Start the stopwatch and remove the finger simultaneously.

6. Stop the stopwatch at the first break in the continuous flow of grout from the discharge opening (when the cone is essentially empty).

7. Read time of efflux of the grout (which is the time indicated by the stopwatch).

   **NOTE 1:** If there is a break in the continuity of discharge prior to essential emptying of the cone, it is an indication that the grout is too thick to be properly tested for flow.

   **NOTE 2:** For the ½ inch orifice, if the sand used in the grout mixture is larger than No. 4 in size, then the sample should be sieved through a No. 4 sieve cloth prior to being introduced to the flow cone.

REPORT – (See Figure 2 for an Example.)

1. Average time of efflux to the nearest second.

2. Composition of the sample

3. Information and observation of the physical characteristics of the sample
FIGURE 1

Grout Flow Cone
FIGURE 2

IOWA DOT DISTRICT 1 LAB
FLOWABLE MORTAR

LAB NUMBER: 1AS4:008
PROJECT NUMBER: CONTRACT NUMBER:
COUNTY: POLK DESIGN:
CONTRACTOR:
MATERIAL: FINE SAND
SOURCE: HALLETT-JOHNSON
UNIT OF MATERIAL: CEMENT-LAFARGE, FLYASH-COUNCIL BLUFFS
QUANTITY: 50 LB BAG
PRODUCER: GNA CONCRETE
SAMPLED BY: SENDER’S NUMBER
DATE SAMPLED: 5/12/04 DATE RECEIVED: 5/12/04 DATE REPORTED: 5/14/04

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>PERCENT PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>100</td>
</tr>
<tr>
<td>#4</td>
<td>99</td>
</tr>
<tr>
<td>#8</td>
<td>92</td>
</tr>
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<td>78</td>
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<tr>
<td>#30</td>
<td>44</td>
</tr>
<tr>
<td>#50</td>
<td>8.2</td>
</tr>
<tr>
<td>#100</td>
<td>0.9</td>
</tr>
<tr>
<td>#200</td>
<td>0.5</td>
</tr>
</tbody>
</table>

DISPOSITION: COMPLIES WITH THE FOLLOWING PROPORTIONS: 400 LBS. FLYASH, 100 LBS. CEMENT, 2600 LBS. SAND. FLOWABILITY OF 16 SEC OBTAINED WITH 68 GAL/YD³ H2O.

COPIES:
DISTRICT 1
DISTRICT 1 MATERIALS LAB
OFFICE OF MATERIALS
S. TWOHEY
J. HART
OFFICE OF CONSTRUCTION
GNA CONCRETE

SIGNED: JOHN HART
MATERIALS ENGINEER
Review Questions
Test for Flow of Grout Mixtures

1. During the testing procedure is the flow cone moistened or left dry?

2. The stop watch is stopped when ________________________________.

3. What does it mean if there is a break of continuity of the discharge before the cone is empty?

4. Describe the steps in calibrating a flow cone.
**READY MIX CONCRETE**

American @ Gilmore City

<table>
<thead>
<tr>
<th>Truck No.</th>
<th>5</th>
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<th>1</th>
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<tr>
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<td>7/17/16</td>
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<td>307</td>
</tr>
<tr>
<td>Proj. No.</td>
<td>FSSN-015-1(7)--3T-76</td>
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<td></td>
</tr>
<tr>
<td>Mix No.</td>
<td>C-4WR-C20</td>
<td>Retarder/Water Reducer?</td>
<td>Yes</td>
</tr>
<tr>
<td>Conc. This Truck</td>
<td>6</td>
<td>C.Y./m³</td>
<td></td>
</tr>
<tr>
<td>Air agent added this truck</td>
<td>18</td>
<td>oz./mL</td>
<td></td>
</tr>
<tr>
<td>Time Batched</td>
<td>7:45 am</td>
<td>Discharged</td>
<td>8:30 am</td>
</tr>
<tr>
<td>Rev. Mixed (Plant)</td>
<td>70</td>
<td>Grade</td>
<td>30</td>
</tr>
</tbody>
</table>

Water (gal./L or lbs./kg This Truck) 8.33 lbs./gal.

| In Aggregate | 49 gal./L | 408 lbs/kg |
| Added (Plant) | 134 gal./L | 1,116 lbs/kg |
| Subtotal      | 183 gal./L | 1,524 lbs/kg |
| Added Grade   | 7 gal./L   | 58 lbs/kg |

TOTAL WATER | 190 gal./L | 1,582 lbs/kg |

Maximum Water Allowed | 209 gal./L | 1,740 lbs./cy or kg/m³ |
Air | 6.8% | Slump | 3" |

Plant Insp. | Joe Smith NW000 |
Receiving Insp. | |
Use the following information to fill in the Ready Mix Ticket. The ticket is from Project #STP-53-4(15)—2C-53 and from Kirk’s Ready Mix.

Truck #4, Ticket#2
Batched at 8:45 AM and Discharged at 9:30 AM
Mixer Revolutions – 72 at plant, 35 at grade
Air agent added this truck – 18 ounces
Percent of air – 6.8%
Slump - 2 ¾ inches
6 c. yds. C-3WR-C15S30 batched on 8/4/10
65 lbs. water per cubic yard in the aggregates
175 lbs. water per cubic yard added at the plant
19 lbs. water per cubic yard added at the grade

The amounts given are in pounds per cubic yard. The tickets want both pounds and gallons per truck.

Remember: Sign the first ticket and write your certification number. Initial the rest of the tickets and write your certification number.
READY MIX CONCRETE

______________________________ Plant

Truck No. ___________________ Ticket No. ___________________

Date ______________________ Des. No. _____________________

Proj. No. _____________________

Mix No. ______________ Retarder/Water Reducer? ☐ Yes ☐ No

Conc. This Truck ______________________ C.Y./m³

Air agent added this truck ______________________ oz./mL

Time Batched _______________ Discharged ________________

Rev. Mixed (Plant) __________ Grade ______________________

Water (gal./L or lbs./kg This Truck) 8.33lbs./gal.

In Aggregate _________ gal./L _________ lbs./kg

Added (Plant) _________ gal./L _________ lbs./kg

Subtotal _________ gal./L _________ lbs./kg

Added Grade _________ gal./L _________ lbs./kg

TOTAL WATER _________ gal./L _________ lbs./kg

Maximum Water Allowed _______ gal./L ______ lbs./cy or kg/m³

Air ___________________ Slump ______________________

Plant Insp. ________________________________

Receiving Insp. ____________________________________
Use the following information to fill in the Ready Mix Ticket. The ticket is from Project #STP-53-4(15)—2C-53 and from Kirk’s Ready Mix.

Truck #8, Ticket #4
Batched at 10:15 AM and Discharged at 11:05 AM
Mixer Revolutions – 70 at plant, 33 at grade
Air agent added this truck – 27 ounces
Percent of air - 7.2%
Slump – 3 inches
9 c. yds. C-4-C15 batched on 8/5/10
64 lbs. of water per cubic yard in the aggregates
183 lbs. water per cubic yard added at the plant
25 lbs. water per cubic yard added at the grade

The amounts given are in pounds per cubic yard. The tickets want both pounds and gallons per truck.

Remember: Sign the first ticket and write your certification number. Initial the rest of the tickets and write your certification number.
**READY MIX CONCRETE**

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Plant Plant No.</td>
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</tr>
<tr>
<td>Truck No.</td>
<td></td>
</tr>
<tr>
<td>Ticket No.</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Des. No.</td>
<td></td>
</tr>
<tr>
<td>Proj. No.</td>
<td></td>
</tr>
<tr>
<td>Mix No. Retarder/Water Reducer?</td>
<td>Yes [ ] No [ ]</td>
</tr>
<tr>
<td>Conc. This Truck</td>
<td></td>
</tr>
<tr>
<td>C.Y./m³</td>
<td></td>
</tr>
<tr>
<td>Air agent added this truck</td>
<td></td>
</tr>
<tr>
<td>oz./mL</td>
<td></td>
</tr>
<tr>
<td>Time Batched</td>
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</tr>
<tr>
<td>Discharged</td>
<td></td>
</tr>
<tr>
<td>Rev. Mixed (Plant) Grade</td>
<td></td>
</tr>
</tbody>
</table>

**Water (gal./L or lbs./kg This Truck) 8.33lbs./gal.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Aggregate</td>
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<tr>
<td>Added (Plant)</td>
<td>gal./L lbs./kg</td>
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<tr>
<td>Subtotal</td>
<td>gal./L lbs./kg</td>
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<tr>
<td>Added Grade</td>
<td>gal./L lbs./kg</td>
</tr>
<tr>
<td>TOTAL WATER</td>
<td>gal./L lbs./kg</td>
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</table>

**Maximum Water Allowed**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>gal./L lbs./cy or kg/m³</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>Slump</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Insp.</td>
<td></td>
</tr>
<tr>
<td>Receiving Insp.</td>
<td></td>
</tr>
</tbody>
</table>
Max Water per cu. yd. for Common Mixes

<table>
<thead>
<tr>
<th>Cubic yds batched</th>
<th>1</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max water allowed per cubic yard (gals)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-3</td>
<td>35.3</td>
<td>141.2</td>
<td>176.5</td>
<td>211.8</td>
<td>247.1</td>
<td>282.4</td>
<td>317.7</td>
<td>353.0</td>
</tr>
<tr>
<td>C-4</td>
<td>36.6</td>
<td>146.4</td>
<td>183.0</td>
<td>219.6</td>
<td>256.2</td>
<td>292.8</td>
<td>329.4</td>
<td>366.0</td>
</tr>
<tr>
<td>C-3WR</td>
<td>33.5</td>
<td>134.0</td>
<td>167.5</td>
<td>201.0</td>
<td>234.5</td>
<td>268.0</td>
<td>301.5</td>
<td>335.0</td>
</tr>
<tr>
<td>C-4WR</td>
<td>34.8</td>
<td>139.2</td>
<td>174.0</td>
<td>208.8</td>
<td>243.6</td>
<td>278.4</td>
<td>313.2</td>
<td>348.0</td>
</tr>
<tr>
<td>M-3</td>
<td>37.8</td>
<td>151.2</td>
<td>189.0</td>
<td>226.8</td>
<td>264.6</td>
<td>302.4</td>
<td>340.2</td>
<td>378.0</td>
</tr>
<tr>
<td>M-4</td>
<td>39.6</td>
<td>158.4</td>
<td>198.0</td>
<td>237.6</td>
<td>277.2</td>
<td>316.8</td>
<td>356.4</td>
<td>396.0</td>
</tr>
</tbody>
</table>
C-4WR-C mix design
- 9.0 cubic yards batched

**Aggregate water**
- 66.6 gals water in aggregate

**Plant Water**
- 220 gals plant water

**Total Water**
- **286.6** gals total water

**MAX water**
- 313 gals
- 26 gals max water allowed to be added to load
- Or 26 gals/9 cubic yards = 2.9 gals per cubic yard
C-4WR-C20 mix design
- 9.5 cubic yards batched

Aggregate water
- 3.25 gals/ cubic yard
- 3.25 x 9.5 = 30.9 gals / load

Plant water
- 221 gals plant water

Total water
- 251.9 gals total water

MAX water
- 34.5 gals/cubic yard
- 34.5 x 9.5 = 328 gals per load
- 76.1 gals max water allowed to be added to the load
- Or 76.1 gals/9.5 cubic yards = 8.0 gals per cubic yard
M-4 mix design
• 7.5 cubic yards batched

Aggregate water
• 11.25 gals / load

Plant water
• 240 gals plant water

Total water
• 251.25 gals total water

MAX water
• 292.5 gals per load
• 41.25 gals max water allowed to be added to the load
• Or 41.25 gals/7.5 cubic yards = 5.5 gals per cubic yard
C-4WR-C mix design
• 10.0 cubic yards batched

Aggregate water
• 49.6 gals water in aggregate

Plant Water
• 270 gals plant water

Total Water
• 319.6 gals total water

MAX water
• 348 gals / 10 yard load
• 28.4 gals max water allowed to be added to load
• Or 28.4 gals/10 cubic yards = 2.84 gals per cubic yard

Max. water from chart = 348 gals/load
M-4 mix design
• 5.0 cubic yards batched

Aggregate water
• $5.68 + 17.03 = 22.71$ gals/load

Plant water
• 157 gals plant water

Total water
• 179.71 total water

MAX water
• 198 gals for 5 cubic yards
• 18.3 gals max water allowed to be added to the load
• Or $18.3$ gals/5 cubic yards = 3.7 gals per cubic yard
Proportion Table 1
Concrete Mixes
Using Article 4110 and 4115 Aggregates
Basic Absolute Volumes of Materials Per Unit Volume of Concrete

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2</td>
<td>0.101</td>
<td>0.150</td>
<td>0.060</td>
<td>0.276</td>
<td>0.413</td>
</tr>
<tr>
<td>A-3</td>
<td>0.104</td>
<td>0.155</td>
<td>0.060</td>
<td>0.306</td>
<td>0.375</td>
</tr>
<tr>
<td>A-4</td>
<td>0.108</td>
<td>0.161</td>
<td>0.060</td>
<td>0.335</td>
<td>0.336</td>
</tr>
<tr>
<td>A-5</td>
<td>0.111</td>
<td>0.165</td>
<td>0.060</td>
<td>0.365</td>
<td>0.299</td>
</tr>
<tr>
<td>A-6</td>
<td>0.115</td>
<td>0.171</td>
<td>0.060</td>
<td>0.392</td>
<td>0.262</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-2</td>
<td>0.088</td>
<td>0.148</td>
<td>0.060</td>
<td>0.282</td>
<td>0.422</td>
</tr>
<tr>
<td>B-3</td>
<td>0.091</td>
<td>0.153</td>
<td>0.060</td>
<td>0.313</td>
<td>0.383</td>
</tr>
<tr>
<td>B-4</td>
<td>0.093</td>
<td>0.157</td>
<td>0.060</td>
<td>0.345</td>
<td>0.345</td>
</tr>
<tr>
<td>B-5</td>
<td>0.096</td>
<td>0.162</td>
<td>0.060</td>
<td>0.375</td>
<td>0.307</td>
</tr>
<tr>
<td>B-6</td>
<td>0.099</td>
<td>0.167</td>
<td>0.060</td>
<td>0.404</td>
<td>0.270</td>
</tr>
<tr>
<td>B-7</td>
<td>0.102</td>
<td>0.172</td>
<td>0.060</td>
<td>0.433</td>
<td>0.233</td>
</tr>
<tr>
<td>B-8</td>
<td>0.105</td>
<td>0.177</td>
<td>0.060</td>
<td>0.461</td>
<td>0.197</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-2</td>
<td>0.110</td>
<td>0.149</td>
<td>0.060</td>
<td>0.272</td>
<td>0.409</td>
</tr>
<tr>
<td>C-3</td>
<td>0.114</td>
<td>0.154</td>
<td>0.060</td>
<td>0.302</td>
<td>0.370</td>
</tr>
<tr>
<td>C-4</td>
<td>0.118</td>
<td>0.159</td>
<td>0.060</td>
<td>0.331</td>
<td>0.332</td>
</tr>
<tr>
<td>C-5</td>
<td>0.123</td>
<td>0.166</td>
<td>0.060</td>
<td>0.358</td>
<td>0.293</td>
</tr>
<tr>
<td>C-6</td>
<td>0.128</td>
<td>0.173</td>
<td>0.060</td>
<td>0.383</td>
<td>0.256</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-3WR</td>
<td>0.108</td>
<td>0.146</td>
<td>0.060</td>
<td>0.309</td>
<td>0.377</td>
</tr>
<tr>
<td>C-4WR</td>
<td>0.112</td>
<td>0.151</td>
<td>0.060</td>
<td>0.338</td>
<td>0.339</td>
</tr>
<tr>
<td>C-5WR</td>
<td>0.117</td>
<td>0.158</td>
<td>0.060</td>
<td>0.366</td>
<td>0.299</td>
</tr>
<tr>
<td>C-6WR</td>
<td>0.121</td>
<td>0.163</td>
<td>0.060</td>
<td>0.394</td>
<td>0.262</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-57</td>
<td>0.134</td>
<td>0.178</td>
<td>0.060</td>
<td>0.314</td>
<td>0.314</td>
</tr>
<tr>
<td>D-57-6</td>
<td>0.134</td>
<td>0.178</td>
<td>0.060</td>
<td>0.377</td>
<td>0.251</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-3</td>
<td>0.149</td>
<td>0.153</td>
<td>0.060</td>
<td>0.287</td>
<td>0.351</td>
</tr>
<tr>
<td>M-4</td>
<td>0.156</td>
<td>0.161</td>
<td>0.060</td>
<td>0.311</td>
<td>0.312</td>
</tr>
<tr>
<td>M-5</td>
<td>0.160</td>
<td>0.165</td>
<td>0.060</td>
<td>0.338</td>
<td>0.277</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>O-4WR</td>
<td>0.156</td>
<td>0.160</td>
<td>0.060</td>
<td>0.312</td>
<td>0.312</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPC-O</td>
<td>0.134</td>
<td>0.164</td>
<td>0.060</td>
<td>0.321</td>
<td>0.321</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPC-S</td>
<td>0.118</td>
<td>0.156</td>
<td>0.060</td>
<td>0.333</td>
<td>0.333</td>
</tr>
</tbody>
</table>
### HPC-D MIXES  Basic w/c = 0.400  Max w/c =0.420

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPC-D</td>
<td>0.118</td>
<td>0.148</td>
<td>0.060</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

### QMC MIXES  Basic w/c = 0.400  Max w/c =0.420

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPC-D</td>
<td>0.106</td>
<td>0.133</td>
<td>0.060</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

### X MIXES  Basic w/c = 0.423  Max w/c =------

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-2</td>
<td>0.124</td>
<td>0.165</td>
<td>0.000</td>
<td>0.284</td>
<td>0.427</td>
</tr>
<tr>
<td>X-3</td>
<td>0.129</td>
<td>0.171</td>
<td>0.000</td>
<td>0.315</td>
<td>0.385</td>
</tr>
<tr>
<td>X-4</td>
<td>0.134</td>
<td>0.178</td>
<td>0.000</td>
<td>0.344</td>
<td>0.344</td>
</tr>
</tbody>
</table>

Above mixtures are based on Type I or Type II cements (Sp. G. = 3.14). Mixes using blended cements (Type IP or IS) must be adjusted for cement gravities listed in IM 401.

*These mixes require optimized aggregate proportioning in accordance with the specifications.

### Proportion Table 2  
Concrete Mixes  
Using Class V Aggregates Combined with Limestone  
Basic Absolute Volumes of Materials Per Unit Volume of Concrete

#### V47B MIXES

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Class V.</th>
<th>Coarse Limestone</th>
<th>Basic w/c</th>
<th>Max. w/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-V47B</td>
<td>0.107</td>
<td>0.148</td>
<td>0.060</td>
<td>0.479</td>
<td>0.206</td>
<td>0.440</td>
<td>0.560</td>
</tr>
<tr>
<td>B-V47B</td>
<td>0.098</td>
<td>0.160</td>
<td>0.060</td>
<td>0.477</td>
<td>0.205</td>
<td>0.520</td>
<td>0.597</td>
</tr>
<tr>
<td>C-V47BF¹</td>
<td>0.113</td>
<td>0.145</td>
<td>0.060</td>
<td>0.477</td>
<td>0.205</td>
<td>0.430</td>
<td>0.488</td>
</tr>
<tr>
<td>M-V47B²</td>
<td>0.155</td>
<td>0.170</td>
<td>0.060</td>
<td>0.338</td>
<td>0.277</td>
<td>0.350</td>
<td>0.400</td>
</tr>
</tbody>
</table>

#### V MIXES

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Class V.</th>
<th>Fine Limestone</th>
<th>Basic w/c</th>
<th>Max. w/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-V</td>
<td>0.135</td>
<td>0.188</td>
<td>0.060</td>
<td>0.586</td>
<td>0.031</td>
<td>0.444</td>
<td>0.467</td>
</tr>
<tr>
<td>B-V</td>
<td>0.135</td>
<td>0.188</td>
<td>0.060</td>
<td>0.586</td>
<td>0.031</td>
<td>0.444</td>
<td>0.467</td>
</tr>
<tr>
<td>C-V</td>
<td>0.135</td>
<td>0.188</td>
<td>0.060</td>
<td>0.586</td>
<td>0.031</td>
<td>0.444</td>
<td>0.467</td>
</tr>
<tr>
<td>M-V</td>
<td>0.160</td>
<td>0.196</td>
<td>0.060</td>
<td>0.555</td>
<td>0.029</td>
<td>0.390</td>
<td>0.420</td>
</tr>
</tbody>
</table>

#### CV-HPC MIXES

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Water</th>
<th>Air</th>
<th>Class V.</th>
<th>Coarse Limestone</th>
<th>Basic w/c</th>
<th>Max. w/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV-HPC-D¹</td>
<td>0.123</td>
<td>0.147</td>
<td>0.060</td>
<td>0.368</td>
<td>0.302</td>
<td>0.400</td>
<td>0.420</td>
</tr>
<tr>
<td>CV-HPC-S¹</td>
<td>0.123</td>
<td>0.155</td>
<td>0.060</td>
<td>0.364</td>
<td>0.298</td>
<td>0.420</td>
<td>0.450</td>
</tr>
</tbody>
</table>

Above mixtures are based on Type I or Type II cements (Sp. G. = 3.14). Mixes using blended cements (Type IP or IS) must be adjusted for cement gravities listed in IM 401.

¹Absolute volumes based on Type IP cement used.
²M-V47B mix shall use Type I/II cements for patching projects.
Proportion Table 3  
Concrete Mixes  
Using Class L Aggregates  
Basic Absolute Volumes of Materials Per Unit Volume of Concrete

<table>
<thead>
<tr>
<th>A-L MIXES</th>
<th>Basic w/c = 0.474</th>
<th>Max w/c = 0.532</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix No.</td>
<td>Cement</td>
<td>Water</td>
</tr>
<tr>
<td>A-L-2</td>
<td>0.107</td>
<td>0.159</td>
</tr>
<tr>
<td>A-L-3</td>
<td>0.111</td>
<td>0.165</td>
</tr>
<tr>
<td>A-L-4</td>
<td>0.115</td>
<td>0.171</td>
</tr>
<tr>
<td>A-L-5</td>
<td>0.118</td>
<td>0.176</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B-L MIXES</th>
<th>Basic w/c = 0.536</th>
<th>Max w/c = 0.600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix No.</td>
<td>Cement</td>
<td>Water</td>
</tr>
<tr>
<td>B-L-2</td>
<td>0.094</td>
<td>0.158</td>
</tr>
<tr>
<td>B-L-3</td>
<td>0.097</td>
<td>0.163</td>
</tr>
<tr>
<td>B-L-4</td>
<td>0.099</td>
<td>0.167</td>
</tr>
<tr>
<td>B-L-5</td>
<td>0.102</td>
<td>0.172</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C-L MIXES</th>
<th>Basic w/c = 0.430</th>
<th>Max w/c = 0.488</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix No.</td>
<td>Cement</td>
<td>Water</td>
</tr>
<tr>
<td>C-L-2</td>
<td>0.117</td>
<td>0.158</td>
</tr>
<tr>
<td>C-L-3</td>
<td>0.121</td>
<td>0.163</td>
</tr>
<tr>
<td>C-L-4</td>
<td>0.125</td>
<td>0.169</td>
</tr>
<tr>
<td>C-L-5</td>
<td>0.131</td>
<td>0.177</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C-LW MIXES</th>
<th>Basic w/c = 0.430</th>
<th>Max w/c = 0.489</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix No.</td>
<td>Cement</td>
<td>Water</td>
</tr>
<tr>
<td>C-L3WR</td>
<td>0.115</td>
<td>0.155</td>
</tr>
<tr>
<td>C-L4WR</td>
<td>0.119</td>
<td>0.161</td>
</tr>
<tr>
<td>C-L5WR</td>
<td>0.124</td>
<td>0.167</td>
</tr>
</tbody>
</table>

Above mixtures are based on Type I or Type II cements (Sp. G. = 3.14). Mixes using blended cements (Type IP or IS) must be adjusted for cement gravities listed in IM 401.

Proportion Table 4  
SUDAS Concrete Mixes  
Using Article 4110 and 4115 Aggregates  
Basic Absolute Volumes of Materials Per Unit Volume of Concrete

<table>
<thead>
<tr>
<th>C-SUD MIXES</th>
<th>Basic w/c = 0.400</th>
<th>Max w/c = 0.420</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix No.</td>
<td>Cement</td>
<td>Water</td>
</tr>
<tr>
<td>C-SUD</td>
<td>0.106</td>
<td>0.133</td>
</tr>
</tbody>
</table>

Above mixture is based on Type I or Type II cements (Sp. G. = 3.14). Mixes using blended cements (Type IP or IS) must be adjusted for cement gravities listed in IM 401. *These mixes require optimized aggregate proportioning in accordance with the specifications.

Using Class V Aggregates (4117) Combined with Limestone  
Basic Absolute Volumes of Materials Per Unit Volume of Concrete

<table>
<thead>
<tr>
<th>CV-SUD MIXES</th>
<th>Basic w/c = 0.400</th>
<th>Max w/c = 0.420</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix No.</td>
<td>Cement</td>
<td>Water</td>
</tr>
<tr>
<td>CV-SUD</td>
<td>0.114</td>
<td>0.135</td>
</tr>
</tbody>
</table>

Above mixture is based on Type IP cements.
Concrete Specifications Summary - April 2020  
(U.S. Units)

Caution: Consult the applicable specifications for required air content and slump before using this chart.

<table>
<thead>
<tr>
<th>Paving</th>
<th>Type of Concrete</th>
<th>Slump (in.)</th>
<th>% Air Content</th>
<th>Specification Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Target</td>
<td>Max.</td>
</tr>
<tr>
<td>Slip form</td>
<td>ABC, QMC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-slip form</td>
<td>ABC, QMC</td>
<td>0.5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Concrete Base</td>
<td>A, C</td>
<td>0.5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>(Non-slip form)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb and gutter (slip form)</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb and gutter (Non-slip form)</td>
<td>C</td>
<td>0.5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sidewalk</td>
<td>B, C</td>
<td>4</td>
<td>5.5</td>
<td>7</td>
</tr>
<tr>
<td>Intakes and manholes</td>
<td>C</td>
<td>4</td>
<td>5.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

**Repair**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>1</th>
<th>3</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>2530.02 B &amp; 2529.02 B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patches with CaCl₂</td>
<td>M-4, M-V</td>
<td>(prior to addition of CaCl₂)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patches without CaCl₂</td>
<td>M</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6.5</td>
<td>8</td>
</tr>
<tr>
<td>Underseal and grouting, flowing mortar</td>
<td>By Flow Cone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Overlays**

|                  |                  |                  |                      |                      |                      | 2310.02 |
| Unbonded, white topping | C, QMC | same as specified concrete | | | | |
| Bonded            | C, QMC           | same as specified concrete | | | | |

**Lighting & Highway Signing**

|                  |                  | 1 | 4 | 5 | 5.5 | 6.5 | 8.5 | 2403.02 A & B |
| Foundation        | C                | 1 | 4 | 5 | 5.5 | 6.5 | 8.5 |              |
# Concrete Specifications Summary - April 2020

(U.S. Units)

Caution: Consult the applicable specifications for required air content and slump before using this chart.

<table>
<thead>
<tr>
<th>Structures</th>
<th>Type of Concrete</th>
<th>Slump (in.)</th>
<th>% Air Content</th>
<th>Specification Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal Coat</td>
<td>X</td>
<td>0</td>
<td>8</td>
<td>2405.02 D</td>
</tr>
<tr>
<td>Sub-Structure &amp; Super-structure</td>
<td>C HPC</td>
<td>1</td>
<td>4</td>
<td>5.5 6.5 8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(when placed by pumping)</td>
</tr>
<tr>
<td>Slope Protection</td>
<td>C</td>
<td>1</td>
<td>3</td>
<td>5.5 6.5 8.5</td>
</tr>
<tr>
<td>Piling encased &amp; Piling brg. (encased)</td>
<td>C</td>
<td>1</td>
<td>4</td>
<td>5.5 6.5 8.5</td>
</tr>
<tr>
<td>Bridge Deck Overlay</td>
<td>O HPC</td>
<td>0</td>
<td>0.75</td>
<td>1</td>
</tr>
<tr>
<td>Brace Deck - Class B Repair</td>
<td>O or D</td>
<td>1</td>
<td>3</td>
<td>5.5 6.5 8.5</td>
</tr>
<tr>
<td>Barrier Rail - Cast in place</td>
<td>C</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Barrier Rail - Slipform</td>
<td>BR</td>
<td></td>
<td></td>
<td>6 7 8.5</td>
</tr>
<tr>
<td>Guardrail</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End anchors</td>
<td>C</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
# Concrete Specifications Summary - April 2020

(U.S. Units)

Caution: Consult the applicable specifications for required air content and slump before using this chart.

<table>
<thead>
<tr>
<th>Paving</th>
<th>Type of Concrete</th>
<th>Slump (in.)</th>
<th>% Air Content</th>
<th>Specification Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Target</td>
<td>Max.</td>
</tr>
<tr>
<td>Slip form</td>
<td>ABC, QMC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-slip form</td>
<td>ABC, QMC</td>
<td>0.5</td>
<td>4</td>
<td>5.5</td>
</tr>
<tr>
<td>Concrete Base (Non-slip form)</td>
<td>A, C</td>
<td>0.5</td>
<td>4</td>
<td>5.5</td>
</tr>
<tr>
<td>Curb and gutter (slip form)</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb and gutter (Non-slip form)</td>
<td>C</td>
<td>0.5</td>
<td>4</td>
<td>5.5</td>
</tr>
<tr>
<td>Sidewalk</td>
<td>B, C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intakes and manholes</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Repair                  |                  | 1    | 3      | 3    | 5    | 7    | 2530.02 B & 2529.02 B |
| Patches with CaCl₂      | M-4, M-V         |      |        |      |      |      |                  |
| Patches without CaCl₂   | M                | 1    | 3      | 4    | 5    | 6.5  | 8    | 2530.02 B & 2529.02 B |
| Underseal and grouting, flowing mortar | By Flow Cone |      |        |      |      |      |                  |

| Overlays                |                  |      |        |      |      |      |                  |
| Unbonded, white topping | C, QMC           |      | same as specified concrete |      |      |      | 2310.02          |
| Bonded                  |                  |      |        |      |      |      |                  |

| Lighting & Highway Signing |      |      |      |      |      |      |                  |
| Foundation              | C       | 1    | 4      | 5    | 5.5  | 6.5  | 8.5 | 2403.02 A & B    |
Concrete Specifications Summary - April 2020
(U.S. Units)

Caution: Consult the applicable specifications for required air content and slump before using this chart.

<table>
<thead>
<tr>
<th>Structures</th>
<th>Type of Concrete</th>
<th>Slump (in.)</th>
<th>% Air Content</th>
<th>Specification Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Target</td>
<td>Max.</td>
</tr>
<tr>
<td>Seal Coat</td>
<td>X</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Sub-Structure &amp; Super-structure</td>
<td>C</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>HPC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope Protection</td>
<td>C</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Piling encased &amp; Piling brg. (encased)</td>
<td>C</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Bridge Deck Overlay</td>
<td>O</td>
<td>0</td>
<td>0.75</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>HPC</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Bride Deck - Class B Repair</td>
<td>O or D</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrier Rail - Cast in place</td>
<td>C</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrier Rail - Slipform</td>
<td>BR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Guardrail

|                                   |                  | Min. | Target | Max. | 4    | 7    | 2403.02 & 2505.03 B |
| End anchors                       | C                | 1    | 4      | 5    |      |      |                       |
# PERFORMANCE EXAM CHECKLIST

## TEMPERATURE OF FRESHLY MIXED CONCRETE

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Obtain sample of concrete large enough to provide a minimum of 3 inches of concrete cover around sensor in all directions?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Use calibrated thermometer:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Accurate to ± 1.0° F?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Temperature range from 0 to 120° F?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Place thermometer in sample with a minimum of 3 inches cover around sensor?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Gently press concrete around thermometer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Read temperature after a minimum of 2 minutes or when temperature reading stabilizes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Complete temperature measurement within 5 minutes of obtaining sample?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Record temperature to nearest 1.0° F?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**COMMENTS:** Pass _____ Fail _____
# PERFORMANCE EXAM CHECKLIST

## SLUMP OF HYDRAULIC CEMENT CONCRETE

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cone and floor base plate dampened?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>2. Cone held firmly against the base by standing on the two foot pieces? Cone not allowed to move in any way during filling?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>3. Representative samples scooped into the cone?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>4. Cone filled in three approximately equal layers (by volume), the first to a depth of 2% in., the second to a depth of 6% in., and the third to just over the top of the cone?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>5. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>6. Middle and top layers rodded to just penetrate into the underlying layer?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>7. When rodding the top layer, excess concrete kept above the mold at all times?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>8. Concrete struck off level with top of cone using tamping rod?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>9. Cone lifted upward 12 in. in one smooth motion, without twisting the cone, in 5±2 seconds?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>10. Slump measured to the nearest (\frac{1}{4})” from the top of the cone to the displaced original center of the top surface of the specimen?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>11. Test performed from the start to finish within 2½ minutes</td>
<td>_____</td>
<td>_____</td>
</tr>
</tbody>
</table>

**COMMENTS:**

Pass _____

Fail _____
**PERFORMANCE EXAM CHECKLIST**

**DENSITY AND YIELD OF CONCRETE**

Participant Name ___________________________________  Exam Date ____________

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weight of empty measure determined?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>2. Measure filled in three equal layers, slightly overfilling the last layer?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>3. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>4. Middle and top layers rodded, each throughout their depths and penetrating the previous layer by approximately 1 in. into the underlying layer?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>5. Sides of the measure tapped 10-15 times with the mallet after rodding each layer?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>6. Any excess concrete removed using a trowel or a scoop, or small quantity of concrete added to correct a deficiency, after consolidation of final layer?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>7. Concrete struck off to a smooth surface with the flat strike-off plate?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>8. All excess concrete cleaned off and weight of full measure determined?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>9. Net weight calculated?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>10. Density calculated</td>
<td>_____</td>
<td>_____</td>
</tr>
</tbody>
</table>

COMMENTS:  Pass ______  Fail ______
# PERFORMANCE EXAM CHECKLIST

## AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Representative sample selected?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Container filled in three equal layers, slightly overfilling the last layer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Bottom layer rodded throughout its depth, without forcibly striking the bottom of the container?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Middle and top layers rodded, each throughout their depths and penetrating 1 in. into the underlying layer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Sides of the container tapped 10-15 times with the mallet after rodding each layer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Concrete struck off level with top of container using the bar and rim cleaned off?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Inside of cover cleaned and moistened before clamping to base?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Both petcocks open?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Air valve closed between air chamber and the bowl?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Water injected through petcock until flows out the other petcock?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Water injection into the petcock continued while jarring and tapping the meter to insure all air is expelled?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Participant Name _____________________________ Exam Date ____________
**Procedure Element**

**Page 2**

13. Air pumped up to initial pressure line?  

14. A few seconds allowed for the compressed air to stabilize?  

15. Gauge adjusted to the initial pressure?  

16. Both petcocks open?  

17. Air valve opened between chamber and bowl?  

18. Sides of bowl tapped with the mallet?  

19. Air percentage read after lightly tapping the gage to stabilize the hand?  

20. Air valve closed and then petcocks opened to release pressure before removing the cover?  

21. Air content recorded to 0.1 percent?  

**COMMENTS:**  
Pass ____  Fail ____
PERFORMANCE EXAM CHECKLIST

FLEXURAL STRENGTH OF CONCRETE USING SIMPLE BEAM
WITH CENTER-POINT LOADING

<table>
<thead>
<tr>
<th>Performance Element</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Draw a reference line on the top and bottom of the beam, as cast, about 10 inches from the end?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Insert stirrup pins?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Place beam in machine so the two reference lines are directly under the center line of center bearing?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 4. Rotate micro pump handle  
   (a) expose the maximum thread? |     |    |
|   (b) close loading valve on pump? |     |    |
| 5. Apply a small initial load and remove pins? |     |    |
| 6. Apply load  
   (a) rapidly to approximate 50% of estimated load with pump handle? |     |    |
|   (b) final half of the loading is accomplished by turning crank of the micro pump, at a rate not to exceed 150 psi per minute? |     |    |
| 7. Measure to nearest .02 inch to determine average width and depth of the specimen at the section of failure? |     |    |
| 8. Measure the distance from the line drawn at the center of the span to the location of the break on the bottom side of the beam as tested? (If the measurement exceeds 1½ inch the results can not be used.) |     |    |

COMMENTS:     Pass ______  Fail ______